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BY

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WITH TECHNICAL DESCRIPTIONS BY

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UNITED STATES DEPARTMENT OF AGRICULTURE WASHINGTON, D. C.

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INTERIOR OF STALKS OF SUGAR CANE SHOWING HOLES MADE BY SUGAR-CANE MOTH BORER AND A BORER IN ITS TUNNEL

The normal tissue is of white or yellowish color, and the reds and other colors are the results of diseases, especially "red rot," which follow the borer in the cane stalk, causing additional deterioration.

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE SUGAR-CANE MOTH BORER IN THE UNITED STATES[1]

By T. E. HOLLOWAY, *Associate Entomologist*, and W. E. HALEY, *Principal Scientific Aid, Division of Cereal and Forage Insects*, and U. C. LOFTIN,[2] *Entomological Assistant, Division of Southern Field Crop Insects*, with Technical Descriptions by CARL HEINRICH, *Associate Entomologist, Division of Taxonomy, Bureau of Entomology*

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INTRODUCTION[3]

Sugar cane is a giant grass known botanically as *Saccharum officinarum* Linnaeus, and is grown from cuttings which are laid lengthwise in the rows. It grows from late spring through the warm months of the year, and must be cut before it is damaged seriously by cold weather.

The plant does not produce seeds in Louisiana, though it does in tropical countries and occasionally in southern Florida and the southern tip of Texas. The stalks are cut in the fall, the leafy tops and side leaves are trimmed off and left on the fields, and the stalks are ground in the mill, this being the first step in the manufacture of sugar. The leaves and tops left on the ground usually are called the "trash," but by some "shucks," and by others "flags."

The principal insect injurious to sugar cane in the United States is a moth generally known in the larva stage as "the borer," but it is distinguished from other boring insects of sugar cane by the names "moth borer" and "lesser moth borer." It is a member of

[1] *Diatraea saccharalis* (Fabricius); order Lepidoptera, family Pyralidae. This bulletin is a revision of and supersedes Department Bulletin No. 746, entitled "The Sugar-cane Moth Borer."

[2] Resigned Jan. 12, 1921.

[3] The work of which this bulletin is a report was done under the general direction of the late W. D. Hunter. The drawings were made by Harry Bradford. Acknowledgment of assistance from others is made at various places throughout the bulletin.

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the order Lepidoptera, family Pyralidae and subfamily Crambinae, and has the scientific name *Diatraea saccharalis* Fabricius. It is this insect which is considered in the following pages.

ESTIMATE OF LOSSES

Not only are the mature canes injured greatly by the moth borer, but many young plants are killed, especially in the early summer. One hundred plants per acre may often be destroyed, but so many plants remain in the field that this loss is not noticeable. It should be prevented, however, because it is on these young plants that the borers multiply in sufficient numbers to become a serious menace to larger canes.

Under calculable losses the injury to mature cane alone will be considered. The full amount of injury is shown only by chemical analysis. Infested and uninfested cane from Texas, not affected by red rot, a disease which often follows borer damage, was analyzed, with the following results:

Uninfested	Per cent	*Infested*	Per cent
Brix	19.5	Brix	17.55
Sucrose	17.45	Sucrose	15.1
Purity	89.5	Purity	86.0

William E. Cross, at that time of the sugar experiment station, New Orleans, La., who made the analyses, stated that the loss due to the moth borer was about 20 per cent of the sugar—a greater loss than might be expected from the figures. John Allbright, chief of the laboratory at Central Chaparra, Cuba, analyzed infested and uninfested cane from a field at that central factory. The results follow:

Uninfested	Per cent	*Infested*	Per cent
Brix	21.3	Brix	18.8
Sucrose	19.9	Sucrose	16.85
Purity	93.4	Purity	89.6
Extraction	47.2	Extraction	36.4

Loss in sucrose, 3.3 per cent in cane.
Loss in sucrose, 15.3 per cent in juice.

Van Dine (*31, p. 11*)[4] and Barber (*2, p. 10–12*) have investigated the losses due to the moth borer in considerable detail.

Barber sums up the effect on sugar content in Table 1, and summarizes his results as follows:

> The sugar-cane borer damages cane in the field by destroying a considerable percentage of the eyes, thus reducing the stand of plant cane; by stunting the growth of the cane, owing to the physical injury of the stem; by admitting fungous diseases through the wounds in the stem; and is the main cause of injury by the wind, owing to the weakening of the stalk due to the tunnels and burrows. These classes of the injury have been appreciated by planters. It now develops that there is another and very important class of injury which has been overlooked. This is the reduction of both the quantity and quality of the juice, which is dealt with specially in this circular. It becomes evident that both the planters and the manufacturers are vitally interested in the work of the sugar-cane borer.

[4] Figures in italics in parentheses refer to "Literature cited," p. 75.

TABLE 1.—*Analysis of sugar cane (D 74) to determine effect on sugar content of the borer injury to cane*

No. of sample	Nature of sample	Weight of cane	Weight of juice	Per cent of juice	Loss of juice due to borer	Total solids in juice	Loss in total solids due to borer	Glucose in juice	Solids not sugar in juice	Glucose ratio	Sucrose in juice	Loss in sucrose due to borer	Purity	Loss in purity due to borer
		Gms.	*Gms.*		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	Borer-free	9,990	6,108	61.1	----	17.1	----	1.6	1.1	11.1	14.4	----	84.2	----
2	Medium infested	11,081	6,735	60.8	0.3	16.1	1.0	1.7	1.2	12.9	13.2	1.2	82.0	2.2
3	Heavily infested	8,824	5,190	58.8	2.3	13.7	3.4	2.1	1.8	21.4	9.8	4.6	71.5	12.7

RESULTS OF ABOVE ANALYSIS FIGURED ON A BASIS OF 1 TON OF CANE TO THE SAMPLE

No. of sample	Nature of sample	Weight of cane	Weight of juice	Loss of juice per ton due to borer	Total solids per ton	Loss in total solids due to borer	Glucose per ton	Increase in glucose due to borer	Solids not sugar per ton	Increase in solids not sugar due to borer	Sucrose per ton	Loss in sucrose due to borer	Actual loss in sucrose due to borer
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*
1	Borer-free	2,000	1,222	------	208.96	-------	19.55	------	13.44	------	175.97	--------	------
2	Medium infested	2,000	1,216	6	195.77	13.19	20.67	1.12	14.59	1.15	160.51	15.46	8.78
3	Heavily infested	2,000	1,176	46	161.11	47.85	24.69	5.14	21.17	7.73	115.25	60.72	34.51

NOTE.—Each sample consisted of 10 canes. Each of the medium-infested canes contained from 1 to 3 infested joints, and each of the heavily infested canes 5 or more infested joints. Analysis made Nov. 12, 1910.

Van Dine states:

There is a direct loss in sugar and a decided reduction in the purity of the juice of cane infested by the moth stalk-borer. This loss in Porto Rico exceeds 670 pounds of sugar per acre of cane in which the infestation was not apparent except upon examination, the yield averaging 41 tons of cane per acre and the stalks being normal and healthy in appearance. The loss increases in direct proportion to the number of joints of the cane stalks infested by the borer. There is more fiber and less juice in borer-infested cane. The actual weight of borer-infested cane is less than that of sound cane, and it is considered that the juice deteriorates more rapidly in infested cane when cane is allowed to stand without being crushed for any length of time after harvest.

In the early bulletin on the moth borer by Stubbs and Morgan (*29, p. 889*) it is found that after the borer became established on Belle Alliance plantation, in Louisiana, there was "a falling off of 4.98 tons per acre, and about 25 pounds sugar per ton." From the figures given in that bulletin it is calculated that an average yield of 3,455 pounds of sugar per acre accrued on Belle Alliance plantation before the borer made its appearance, whereas the average yield thereafter was only 2,393 pounds per acre. The loss in sugar from these figures would be 1,062 pounds per acre. At $0.0435 per pound, which is given as the average price of (white) sugar for three years, the annual money loss per acre due to the moth borer would be $46.20.

As calculated from the figures of Barber (*2*), a similarly high loss is obtained. Barber estimates a total loss of 1,078 pounds of sucrose per acre where canes are all bored, as they sometimes are. The present writers estimate the loss of 96 test sugar as 1,082.33 pounds

per acre. The average price of this grade of sugar on the New Orleans market during the 14 years from 1900 to 1913, inclusive, was approximately 3.87 cents per pound. At this price the money loss where all canes are bored is $41.88 per acre.

During the six-year period from 1912 to 1917, inclusive, in which observations were made, the average infestation was about 58 per cent of all the canes in the infested area in Louisiana, which includes the whole sugar belt, except the parishes of Rapides and most of Avoyelles, or about 300,000 acres planted in sugar cane. Fifty-eight per cent of the maximum loss ($41.88) is $24.29 per acre. For 300,000 acres it reaches the high figure of $7,287,000.

Observations since 1917 have shown similar conditions annually. During recent years the writers have cooperated with the Bureau of Agricultural Economics in estimating the damage. That bureau sends questionnaires to sugar planters and forms its estimate from the answers received, while the writers calculate the loss from their own field observations; that is, if the examinations in a parish should reveal an average stalk infestation of, say, 30 per cent, the loss is calculated as 30 per cent of what would be the loss if every stalk were bored (1,000 pounds of sugar per acre or about 33⅓ per cent of the crop), this working out in this case as a loss for the parish of 10 per cent.

The estimates thus obtained by widely different methods are surprisingly close. The combined estimates of the two bureaus of the loss caused by the moth borer for 1922 was 17 per cent of the normal crop; for 1923, 23 per cent; for 1924, 13 per cent; for 1925, 30 per cent; for 1926, 16 per cent; and the average annual loss, 19 per cent. The actual loss in short tons of sugar for the acreage in Louisiana used for sugar alone (excluding the acreage used for "seed" and for sirup) is shown in Table 2.

TABLE 2.—*Actual sugar losses in the Louisiana area due to the moth borer from 1922 to 1926 inclusive*

Year	Acreage	Loss of sugar (short tons, 2,000 pounds)	Year	Acreage	Loss of sugar (short tons, 2,000 pounds)
1922	241,433	61,565	1925	190,248	85,612
1923	217,259	74,954	1926	159,800	38,352
1924	162,640	31,715			

The losses beginning with the year 1912 are shown in Figure 1. For the years before 1922 the estimates are based on examinations by the writers only.

None of these figures take into consideration the losses caused by injury to corn, which must be serious, but are difficult to estimate, nor is any loss estimated for Texas, Mississippi, or Florida.

CHARACTER OF INJURY TO SUGAR CANE

The work of many insects is apparent immediately, even to the untrained observer, but the injury due to the sugar-cane moth borer is the more serious for the reason that it is not noticeable except on

close examination. To the casual observer one field of sugar cane is like many others. If the leaves are pulled away from a stalk, however, a few holes may be observed in the rind and perhaps a quantity of sawdustlike material may be seen clinging to the stalk. This is evidence that the moth borer has been at work. If the stalk is split lengthwise, tunnels about an eighth of an inch wide may be found running for several feet (see frontispiece), several tunnels sometimes joining in such a way that the plant is greatly weakened and is easily blown down by a high wind.

It is evident that such injury must occasion various forms of loss in tonnage of cane, pounds of manufactured sugar, etc. The injury is

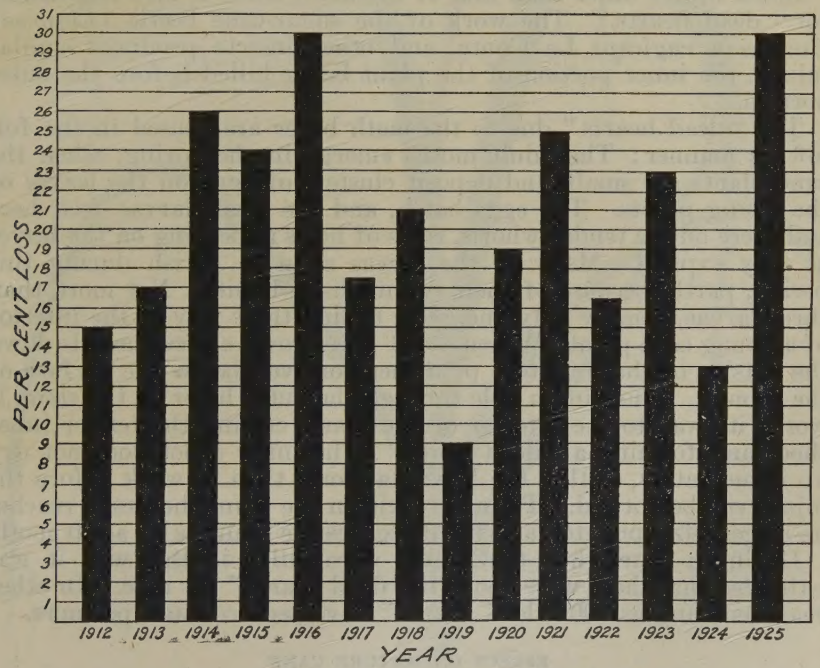

FIG. 1.—Estimated loss of sugar cane in Louisiana caused by the sugar-cane moth borer, 1912–1925

rendered even more serious by the insidious habits of the insect, since the full amount of damage is underestimated by the average planter. Only by walking through the field and examining stalk after stalk can any definite idea of the full amount of injury be obtained.

EFFECT ON YOUNG CANE—"DEAD HEARTS"

The first injury of the moth borer to the young sugar-cane plant produces what is known as the "dead heart." This injury is illustrated in Plate 1. Among plants from 6 inches to 3 feet in height some usually are to be found in which the outer leaves are a healthy green while the young, inner whorl is yellow and dry. The central portion, or "heart," of the plant is dead, and the dying of the rest of the plant is only a matter of days.

This peculiar reaction to injury is rather characteristic of young cane. It is often due to the work of the borer, but it may result from various other causes. Thus some "dead hearts" are caused by a twisted growth of the inner tissues of the plant, the tissues above such a twist ultimately dying. Other "dead hearts" result from accidents of cultivation. A false step of the mule or the plowman may break the brittle inner tissues near the ground while the outer portion of the plant, being stronger and more elastic, springs erect after the weight is removed. In a short time the heart dies, and an investigation will show that the inner tissues have been broken cleanly and have turned slightly brown at the point of separation.

Insect injury other than that of the moth borer is also responsible for "dead hearts." The work of the sugar-cane beetle (*Ligyrus*) *Euetheola rugiceps* Le Conte, and other insects produces similar injury, the inner portion of the plant being killed before the outer portion.

The "dead hearts" due to the moth borer are caused in the following manner: The adult moths emerge in the spring, when the cane plants are small, and deposit clusters of eggs on the leaves of the young plants. The eggs hatch, and the small larvae feed here and there on the tender whorls, rows of holes appearing on the leaves as they expand. Many of the larvae seem to perish during this period, partly because of their cannibalistic habits. Not more than three larvae, usually only one, seem to find their way to the interior of a young cane plant. When about half grown a larva crawls down the outside of the stem to a point near or even below the surface of the ground. Gnawing a hole through the outer layer of the stem, it works its way to the interior of the plant, cutting the tender inner shoot and forming a "dead heart." The inner shoot does not dry up immediately, so that the larva has some time to work before the injury can be noticed. Tunneling within the plant the insect reaches its largest size, pupates, and finally leaves the plant as an adult moth.

During a year when few plants were killed in this way it was estimated that there were about 10 "dead hearts" per acre. In other years as many as 100 "dead hearts" have been counted per acre.

EFFECT ON MATURE CANE

While the work of the larvae on the small plants kills the plants, larger stalks usually do not die. In these the larvae burrow up and down, sometimes gnawing their way out through the hard rind and reentering at another point. Frequently a mature stalk will harbor two or three larvae, which work in different parts of the cane from the top to the bottom. Three sections of infested cane are illustrated in the frontispiece.

A red coloration, showing in the canes illustrated, usually is observed in the pith along the tunnels. This is the disease "red rot," which is caused by the fungus *Colletotrichum falcatum*. "By far the largest number of stalks become infected (with red rot) through the burrows made by the cane borer," writes Edgerton (*10, p. 9, 11, 17*), who sums up the injury due to red rot as follows: "First, the loss in stand; second, the killing of the young plants; third, the injury to the leaves; fourth, the loss in per cent of sucrose with a

"DEAD HEART" CAUSED BY THE SUGAR-CANE MOTH BORER

Injury of this character results, in a few days, in the death of the young plant.

corresponding increase in glucose." "Knowing that a large per cent of the red-rot infection in cane is by means of borer channels," Edgerton continues, "a greater effort should be made to control the insect."

The spores of other fungi, as well as bacteria,[5] also gain entrance through the borer holes. Cane badly bored is found to be hard and dry, and is more difficult to grind. The growth is checked, and the bored stalks are often blown down by a strong wind. The purity of the juice is lowered, the tonnage decreased, and the sucrose content materially diminished. The eyes are destroyed in many cases, which lessens the value of the infested cane for seed.

EFFECT ON CORN

The damage of the moth borer[6] to the corn plant has been well described by Ainslie (*1*, *p. 2*).

> Corn is damaged by these caterpillars in two ways. First, in the early part of the season, while the plants are small, they work in the "throat" of the young corn, and if the tender growing tip within the protecting leaves is once damaged all chances that the plant will become a normal productive specimen are gone. In many sections of the South this is commonly known as "bud-worm" injury, and though there are several other insects which cause a similar mutilation of the leaf, a very large proportion of the so-called "bud-worm" damage may be charged to this insect. The effect of its work on the leaves of the young corn plants is similar to that resulting from attacks by the corn billbugs (*Sphenophorus* spp.) and is evidenced by the familiar rows of small circular or irregular holes across the blades of the plant.
>
> The other form of serious damage chargeable to this pest occurs later in the season. The larvae, having then left the leaves and descended to the lower part of the stalk, tunnel in the pith. If the larvae are at all numerous in the stalk, their burrows so weaken the plant that any unusual strain will lay it low and destroy all chance of its maturing. While frequently 10 or more larvae may live and mature in one plant, it must be remembered that any infestation, however light, will lessen in some degree the vitality of the plant and cause a corresponding loss in the quality and quantity of the harvest.

Not only the stalks of corn, but sometimes the ears are found to contain borers.

The cornstalks, maturing about July or August, when the cane is hardly half grown, become dry, and the plants are no longer attractive to the moths for the deposition of eggs. Corn and cane are grown in adjacent fields on Louisiana sugar plantations, and moths from corn find cane an attractive food plant. Consequently the cane in the middle of the season is attacked not only by moths which have passed their immature stages in cane plants, but by numbers of those which have grown to maturity in corn. It is notable that the number of cane stalks infested by borers increases rapidly from the middle of the growing season until the cane is cut.

EFFECT ON RICE

J. W. Ingram, of the Bureau of Entomology, has found that the sugar-cane moth borer does more damage to rice than does the rice

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[5] Wm. L. Owen (*25*, *p. 239*), bacteriologist, of the Louisiana State University, has studied and described a bacterium which he found in the tunnels made by the moth borer in sugar cane. He has given it the name of *Bacillus saccharalis*.

[6] Though this account was doubtless written with *Diatraea zeacolella* Dyar in mind, it is correct when applied to the closely allied species, *D. saccharalis*, which also attacks corn.

stalk borer (*Chilo plejadellus* Zincken). The larvae of both species tunnel through the stem of the rice plant, causing the plant to die. In mature plants the "head" of the plant turns white instead of ripening normally. The damage from the sugar-cane moth borer is mostly in the vicinity of corn or sugar-cane fields or near the edges of fields where the borers can hibernate in large grasses.

Fortunately, the damage to present varieties of rice is usually slight, but it is more serious on thick-stemmed varieties which at present are being planted in an experimental way.

HISTORY

Howard (*18, p. 95–97*) wrote an article on the moth borer for the official entomological journal, Insect Life, in 1891, introducing his remarks with an account of the history of the species. The account is as follows:

> The attention of English-speaking people was first called, in a scientific way, to the ravages of a lepidopterous borer in sugar cane by the Rev. Lansdown Guilding in his account of the insects infesting sugar cane, in the Transactions of the Society of Arts, 1828, vol. XLVI, pp. 143–153. He described the insect as *Diatraea sacchari*, and for his paper, which comprehended also an account of the sugar-cane and palm weevils, he was awarded the gold Ceres medal of the society. His studies were made in the Island of St. Vincent in the West Indies, and from its occurrence there at this early date, and from Guilding's statement that it had been long known, there is reason to suppose that the insect may be an indigene of South America or of the West Indies, where the cultivation of sugar cane was first begun in America.
>
> In 1856 a select committee, appointed to investigate the damage caused by the cane borer in Mauritius, reported through W. Bojer, and the insect, which is called in the report *Proceras sacchariphagus*, was treated at some length, and an account was given of its introduction into the island. In the same year Westwood reviewed this report at length in the Gardeners' Chronicle of July 5, gave a woodcut of the insect, and pointed out that it was probably identical with the species described by Guilding at St. Vincent. He also called attention to the fact that the species named many years previously by Fabricius as *Phalaena saccharalis* is probably the same thing. This insect was described by Fabricius (Entomologia systematica, vol. III, part 2, p. 238), from South America, no more definite locality being given. The probabilities are, however, that he refers to Dutch Guiana on account of the early settlement of that country and from the fact that he refers to a figure of the larva by Myhlenfels. He makes the statement that it feeds in sugar-cane, perforating and destroying the stalks and becoming a pest in plantations. He describes the larva as six-footed, of a pale hyaline color, and with the head and eight spots brown. The larval description, however, is drawn from a figure by Myhlenfels, which may have been inaccurate. As Fabricius's work was published in 1793, further evidence is thus afforded that the insect is indigenous to the western hemisphere. This insect still does similar damage in the vicinity of the original source of our information, as is indicated by two articles by Miss Ormerod in the Proceedings of the Entomological Society of London, 1879, XXXIII–XXXVI and XXXVI–XL, and by reports of Mr. Im-Thurm, curator of the British Guiana Museum at Georgetown, published some time previously, but which we have not seen.
>
> In an added note to his Gardeners' Chronicle article, Westwood states that according to information given him by "an intelligent Jamaica cane-grower" the borer was very destructive in Jamaica some 15 years previously (1842), but that its ravages had been greatly checked by allowing the refuse to accumulate on the ground and then firing the whole plantation, the old roots subsequently throwing up more vigorous shoots.
>
> Mr. H. Ling Roth has studied what he believes to be the same species in Queensland (Parasites of the Sugar-Cane, reprinted from the Sugar Cane, March and April, 1885. London, 1885). And in the same year M. A. Delteil (La Canne á Sucre, Paris, 1885) treats of the Mauritius borer and considers it

to have been imported from Java, whereas the 1856 commission had considered that it was derived from Ceylon. In 1890 Dr. W. Kruger published in the Berichte der Versuchsstation für Zuckerrohr in West Java, Heft 1, Dresden, 1890, an account of the sugar-cane borers. and figures and describes a species determined as *Diatraea striatalis* Snell., which almost precisely resembles our species, and which he says occurs not only in Java, but also in Borneo, Sumatra, and Singapore. In this same report another similar borer is described by Snellen as *Chilo infuscatellus.*

The West Indian cane borer made its appearance in the sugar-cane plantations of Louisiana at an early date. J. B. Avequin, writing in the Journal de Pharmacie for 1857 (vol xxxii, pp. 335–337), upon the enemies of the sugar cane in the Antilles and Louisiana, stated that during the two or three preceding years this insect had spread over some of the cane fields of Louisiana, but without having caused up to that time any great damage. He thought that the early frosts towards the end of October or November destroyed great numbers. It appears to have been first noticed in the Parish of St. John Baptist in the year 1855.

Since this time the insect must have been constantly present in the Louisiana cane fields, and has probably been reintroduced from time to time with fresh shipments of seed cane from the West Indies. In the fall of 1878 a few specimens were sent to Dr. Riley by a correspondent of Assumption Parish, Louisiana, and in the spring of 1879 Mr. E. A. Schwarz sent in a bit of cane containing larvæ from the Bahamas. In the spring of 1881, I was sent to Louisiana by Professor Comstock, then entomologist of the Department of Agriculture, to study the sugar-cane beetle (*Ligyrus rugiceps*), and had the opportunity of studying this borer upon the plantation of Dr. J. B. Wilkinson, some 40 miles south of New Orleans on the Mississippi River. Dr. Wilkinson informed me that in 1857 they were very abundant in the Lower Mississippi, and that the crop upon one plantation was utterly destroyed, the cane breaking to pieces as they attempted to cut it.

Concerning the date of the introduction of the moth borer into Louisiana, Stubbs and Morgan (*29, p. 898*) conclude that it was introduced long before 1857. "How and when the borer was introduced is not certain," they decide, "but the separate corroborating testimony of Mr. Chamberlain and Mr. Maurin would rather fix the date at 1857, and as canes in large quantities from South America were that year introduced, it is reasonable to conclude that they came from that country as asserted by Mr. Maurin, and not from the West Indies, as Mr. Chamberlain thinks. However, if Colonel Pugh and Mr. Bird are accurate in their dates, it was here in quantities before that year." In a footnote to the foregoing these investigators add: "Subsequent investigations have proven that the borer was here in quantities long before the importations of cane described above."

A little-known book by Champomier (*7, p. vii*), who issued a series of statistical reports on the sugar industry of Louisiana about the middle of the last century, mentions the "borer worm" in his report for 1856–57. This reference was brought to the attention of the writers by Edward Foster, of New Orleans.

DISTRIBUTION

The distribution of the sugar-cane moth borer was formerly limited to the southern tip of Texas, most of the southern part of Louisiana, the southwestern point of Mississippi, and possibly the coast of that State, and about the southern half of Florida. The area inhabited by it has been considerably extended since 1916, when a number of field examinations were made. Territory has been acquired in the southwestern part of Louisiana, the area in the southwestern corner of Mississippi has been enlarged to the east and

north, and, most noteworthy, the southeastern corner of Texas and the Texas coast in general have become infested. The infestation of the coastal area of Mississippi possibly occurred during recent years, but old records are not available. It is remarkable that the infested area in Florida has been but little extended on the east coast, and farther west it may even have receded. Loftin recorded the moth borer at Gainesville in 1913, 1914, and 1915, but it could not be found in 1925 by Dan D. Ewing, jr. It is possible that the borers formerly found were of the species *D. zeacolella*, which at that time was not clearly differentiated from *D. saccharalis*, at least not in the larval stage.

Some records indicate that the transportation of infested cane, or use of freight cars in which infested cane has been shipped, may be responsible for the increase in the area infested. For instance, in 1917 no borers could be found at Wharton, Tex., but they were present in 1919. An intelligent farmer and sirup manufacturer of Wharton gave the explanation that borer-free cane had been shipped from Wharton to the lower Rio Grande Valley, where the seed cane had been ruined by the insect. For shipping the good cane, freight cars which had already been used for hauling cane were sent from the southern points to Wharton, and it is believed that these cars contained pieces of infested cane which carried the insect there. Similarly, Kingsville, Tex., was not infested in 1917, but it was infested in 1919. R. A. Vickery, of the Bureau of Entomology, stated that several years previously infested cane from the lower Rio Grande Valley had been sent to Riviera, about 14 miles south of Kingsville.

In regard to the infestation in the southwestern corner of Mississippi, J. E. McEvilly, of the Mississippi Plant Board, writes: "I believe that this pest was brought from Louisiana by negro cane harvesters that go from that section of Mississippi to the Louisiana cane fields every year. The negroes have been in the habit of bringing cane back home after the harvest is over." Without doubt, some new territory is gained by the flight of the moths.

The records for the Mississippi coast were obtained by L. P. O'Dowd and the senior writer, in cooperation with employees of the Mississippi Plant Board, especially E. K. Bynum.

A general survey of all infested areas was made in 1925 by Dan D. Ewing, jr., temporarily employed by the Bureau of Entomology.

SPECIES OF DIATRAEA

Dyar & Heinrich (*8*) record five species of Diatraea in the United States. These are:

Diatraea saccharalis Fabricius, Tropical America from Gulf Coast of United States to Mexico and Argentina (including West Indies).

Diatraea evanescens Dyar, Guatemala, Louisiana, Mississippi.

Diatraea zeacolella Dyar, Virginia, North Carolina, South Carolina, Florida, Kansas.

Diatraea venosalis Dyar, Louisiana.

Diatraea grandiosella Dyar, Mexico (Los Mochis and Venadio, Sinaloa, Colima, Guadalajara, Tehuacan), southwestern Texas, southern New Mexico, and Arizona.

Dyar has determined the species from Louisiana as *Diatraea saccharalis*.

The authors' observations indicate that *D. zeacolella* occurs in Georgia and northern Florida, as well as in the Carolinas and Virginia. In places in these States where both corn and sugar cane are grown this species has been found to be abundant in corn while rare or absent in adjoining cane fields. Practically, it may be regarded as an enemy of corn exclusively. The larval characters which distinguish *D. zeacolella* from *D. saccharalis* have been noted elsewhere by the senior writer (*17*) and have been further investigated by Heinrich. (See description of larva, p. 15.)

D. saccharalis occurs in both corn and sugar cane in the area infested by this variety.

A species in southern Arizona, resembling Diatraea but described by Dyar as *Chilo loftini*, was observed by the writers at Phoenix, Ariz., on sugar cane and Johnson grass. It has the distinctive habit of feeding on the leaves of cane until rather large, before entering the stalk. This species also occurs at Los Mochis, Sinaloa, Mexico, as reported in manuscript reports to the United Sugar Companies

FIG. 2.—Distribution of the sugar-cane moth borer (*Diatraea saccharalis*) in the United States

by R. H. Van Zwaluwenburg, who has also found *C. morbidellus* Dyar there. He has reared *morbidellus* from sugar cane and *loftini* from both sugar cane and rice.

A large pink larva, boring in sugar cane on the Mississippi coast and found by E. K. Bynum and the senior writer (*6, p. 470*), has been described by Dyar as *Meropleon cosmion.*

FOOD PLANTS

Among food plants other than sugar cane and corn are broomcorn, Kafir corn, Johnson grass (*Holcus halepensis*), milo maize, sorghum, Sudan grass (*Andropogon sorghum* var. *sudanensis*), Para grass (*Panicum barbinode*), vetiver (*Andropogon muricatus*), feather grass (*Lectochloa mucronata*), Egyptian wheat, and giant broom sedge. Jones (*20, p. 12*) records *Hymenachne amplexicaule* as a food plant in Porto Rico, and in Louisiana he and Bradley (*21, p. 394*) record *Panicum barbinode*, *Paspalum larrañagae*, *Panicum gymnocarpon*, *P. dichotomiflorum*, *Holcus halepensis*, and *Andropogon glomeratus.* Bodkin (*4, p. 6*) lists rice as a food plant in British Guiana, and the writers have found the moth borer in rice

in Louisiana. Some of these plants were identified by the late R. S. Cocks, of Tulane University, and others by C. W. Edgerton, of Louisiana State University.

A large larva will almost fill the interior of a stalk of rice or grass, but the stalk will nevertheless develop successfully.

The number of food plants, some of which grow wild about plantations, makes the species more difficult to control than if it were limited to corn and sugar cane, the larvae being able to grow to maturity on wild grasses and the adults migrating to the corn and cane fields.

FIG. 3.—Cluster of sugar-cane moth-borer eggs nearly ready to hatch. Much enlarged

LIFE CYCLE IN BRIEF

Emerging in the spring, the adult females deposit their eggs on the young plants of sugar cane, corn, etc. These eggs hatch, the young larvae feeding here and there on the leaves for a short time and then boring into the stalks. After reaching their full development the borers pupate, and in a few days the moths emerge and mate. Eggs are again deposited, and the life cycle is repeated again and again until winter, during which the larval period is prolonged until spring. The overwintering larvae then pupate, moths emerge, and the cycle is repeated.

DESCRIPTION OF STAGES OF LIFE CYCLE

THE EGG

The eggs are round-oval, flattened, about 1.16 mm. long by about 0.75 mm. wide,[7] and are deposited in clusters, overlapping one another (fig. 3), like scales on a fish. A group or cluster contains from 2 or 3 to 50 or more eggs. The clusters vary in shape as well as in size, a small one often being irregularly round, while the larger ones are much longer than wide—sometimes more than 12 mm. long by 3 mm. wide. They are white at first, but later an orange hue develops. They are lightly sculptured with an irregular network of depressed lines resembling the "pebble grain" of leather, which is visible with a microscope. Just before hatching the black heads of the young larvae are plainly visible through the eggshell, and the eggs assume a blackish hue.

[7] 1 millimeter is about one twenty-fifth of an inch.

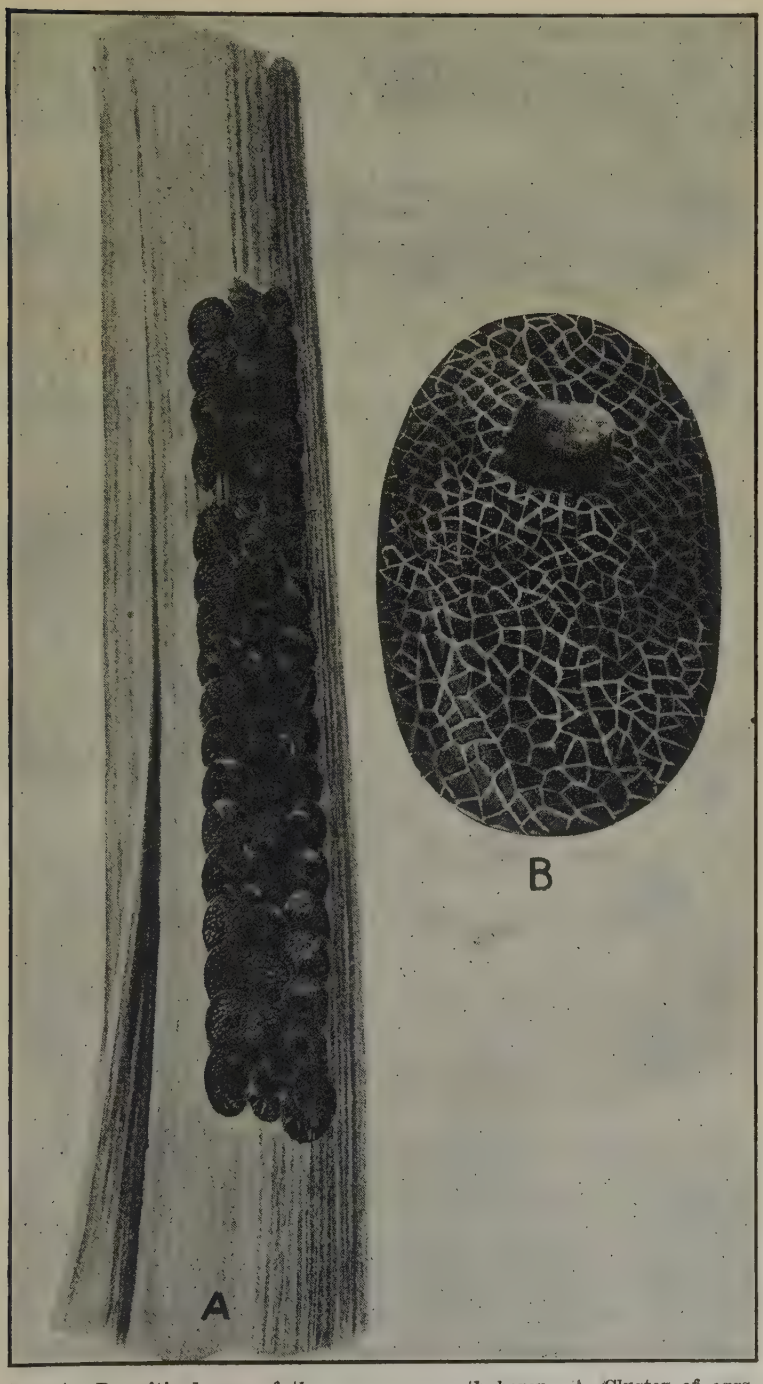

FIG. 4.—Parasitized eggs of the sugar-cane moth borer. A, Cluster of eggs which have been parasitized, much enlarged (note dark appearance and emergence holes of parasites); B, individual parasitized egg, very much enlarged, showing dark appearance and emergence hole of parasite

Eggs may be deposited on either side of a leaf. The fresh ones are very difficult to find, their whiteness blending with the green of the cane or corn leaf. They are securely glued to the leaf surface and in nature are never detached before hatching. After the eggs have hatched, the empty shells become translucent white. The appearance

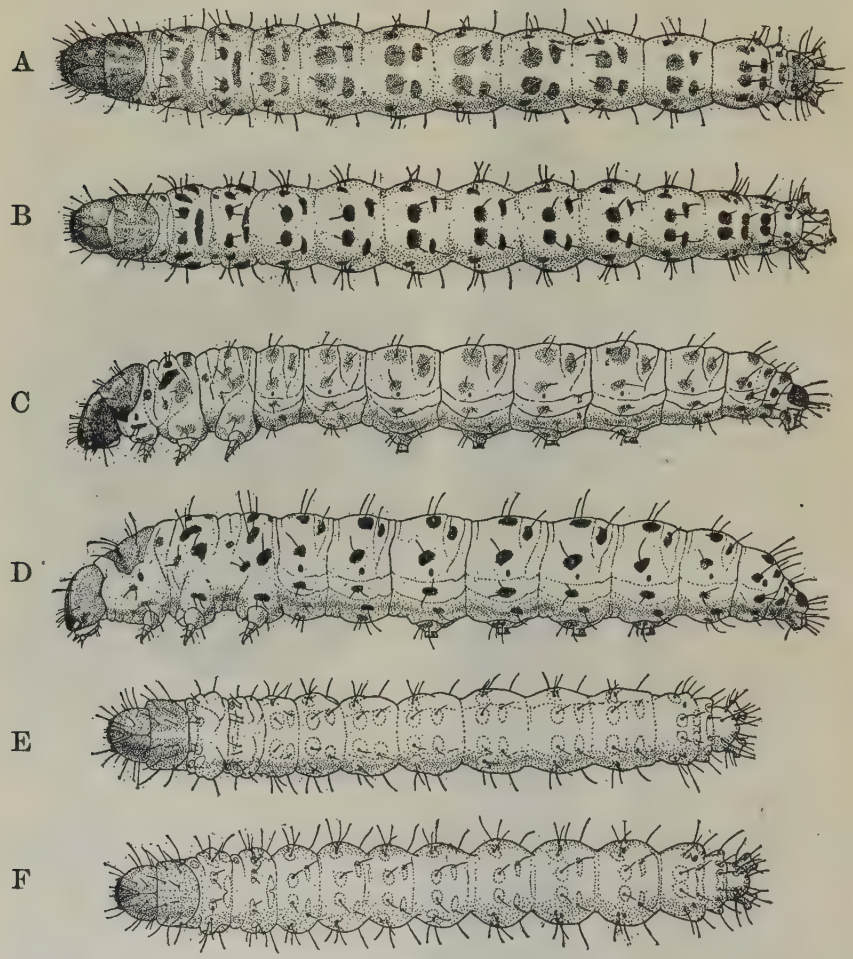

FIG. 5.—Larvae of the sugar-cane moth borer and the larger cornstalk borer. A, The sugar-cane moth borer (*Diatraea saccharalis*), larva, summer form, dorsal view; B, the larger cornstalk borer (*D. zeacolella*), larva, summer form, dorsal view; C, *D. saccharalis*, larva, summer form, side view; D, *D. zeacolella*, larva, summer form, side view; E, *D. saccharalis*, larva, winter form, dorsal view; F, *D. zeacolella*, larva, winter form, dorsal view.

of a cluster of eggshells from which the larvae have emerged has been well likened to a fragment of cast snake skin.

When parasitized the eggs gradually turn jet black and remain so even with the emergence of the parasites. Because of their color, parasitized eggs are much more easily detected in the field than are the normal eggs. The holes made by the parasites in emerging are readily discernible. (Fig. 4.)

THE LARVA

The larva, which is the form of the insect most familiar to sugar planters, is when full-grown about 1 inch long by one-eighth inch wide. In this form the insect commits its ravages. The head is brown and the body white with brown spots. This is the summer coloration of the larva, but in the winter it loses its spots, and the body assumes a uniform dirty white color.

Technical descriptions of both the winter and summer forms (full-fed larvae) have been published elsewhere by the senior writer (*17, p. 623–624*), and they have now been corrected by Heinrich to conform to the latest knowledge of lepidopterous larval characters. His descriptions are given below.

GENERAL CHARACTERS

No secondary hairs. Legs and prolegs normal. Crochets triordinal and in a complete circle. No anal fork. Prothoracic shield broad, divided. A narrow pigmented shield on mesothorax, caudad of setae I*a* and I*b* bearing no setae. Spiracles elongate oval; prothoracic spiracle twice the size of those on abdominal segments 1 to 7; that on segment 8 slightly larger than prothoracic and slightly dorsad of other abdominal spiracles. (Fig. 5, A, C, E, and fig. 6, A.)

Body setae (fig. 6, A) moderately long; tubercles prominent, broadly chitinized; IV and V on abdominal segments 1 to 8 under the spiracle and approximate; prespiracular shield of prothorax narrow, horizontally elongate, bearing only two setae (IV and V) situated ventrocephalad of the spiracle, III of prothorax absent; group VI bisetose on prothorax, mesothorax, and metathorax; [8] IV and V united on abdominal segment 9 and approximate to III; III above the spiracle on abdominal segments 1 to 7, before the spiracle on abdominal segment 8; III*a* rudimentary or indistinguishable, before the spiracle on abdominal segments 1 to 7, ventrocephalad of the spiracle on abdominal segment 8; group VII trisetose on abdominal segments 3 to 7, unisetose on abdominal segments 8 and 9; abdominal segment 9 bearing six prominent setae in a nearly vertical line, I rudimentary or absent, when distinguishable it is laterocephalad of II and equidistant from II and III; on the other abdominal segments II is slightly shorter than, and laterocaudad of I; setae and punctures on prothoracic shield as follows: I*a*, *b*, *c* behind the frontal margin of the shield, distance separating I*b* and I*c* equal to that between II*a* and II*b*, II*a* dorsocaudad of I*a*, puncture *z* slightly lower than the level of II*b*, punctures *x* and *y* dorsocaudad of I*a*, distance between I*c* and II*c* slightly less than that between I*b* and I*c*.

Head capsule (fig. 6, B, D) spherical, slightly trapezoidal or broadly oval (nearly square) in outline viewed from above, as wide or a trifle wider than long; greatest width back of middle of head; incision of dorsal hind margin slight; distance between dorsal extremities of hind margin less than one-half the width of the head. Frons (FR) a trifle longer than wide, not quite reaching to middle of head; adfrontal ridges (ADFR) parallel from lower limit of epistomal area to point of juncture of tentorial arms, thence converging in slightly curved lines to the longitudinal ridge (LR); longitudinal ridge slightly longer than frons; adfrontal sutures (ADFS) meeting longitudinal ridge slightly behind middle of head. Projection of dorsal margin over ventral less than one-half the diameter of the head.

Ocelli six (fig. 6, D); I larger and III smaller than the others; III and IV closer together than any of the others.

Epistoma (fig. 6, B, D) with the normal setae (E^1, E^2).

Frontal punctures (fig. 6, B, D) (F^u) very close together and immediately between the frontal setae (F^1); distance from frontal seta (F^1) to seta Adf^1 about equal to distance separating adfrontal setae (Adf^1 and Adf^2); Adf^2 well behind beginning of longitudinal ridge; puncture Adf^a equidistant from Adf^1 and Adf^2 and approximate to beginning of longitudinal ridge.

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[8] This is the Pi group of Fracker, which he erroneously describes as unisetose in the Crambinae. (*12, p. 87, 91.*)

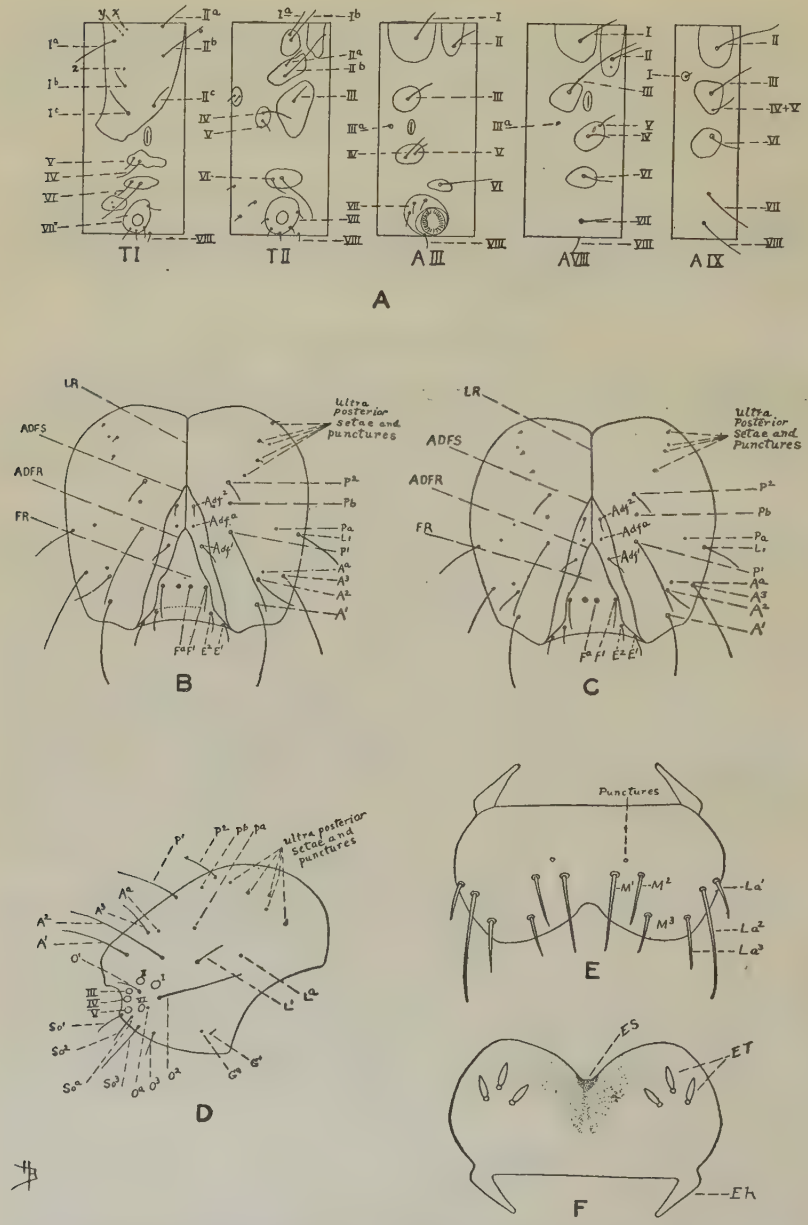

FIG. 6.—Larval details of the sugar-cane moth borer and the larger cornstalk borer. A, The sugar-cane moth borer (*Diatraea saccharalis*), larva, setal maps of body; B, *D. saccharalis*, larval head capsule, dorsal view; C, the larger cornstalk borer (*D. zeacolella*), larval head capsule, dorsal view; D, *D. saccharalis*, larval head capsule, lateral view; E, *D. saccharalis*, larval labrum; F, *D. saccharalis*, larval epipharynx

Epicranium (fig. 6, B, D) with the normal number of primary setae and punctures and with three ultraposterior setae and one or two ultraposterior punctures. Anterior setae (A^1, A^2, A^3) in a right angle; A^2 equidistant from A^1 and A^3; anterior puncture posterior to A^2. Posterior setae (P^1, P^2) and puncture (P^b) of posterior group lying parallel with longitudinal ridge; P^1 nearly on a level with beginning of longitudinal ridge; P^2 on, or nearly on a level with place of juncture of adfrontal sutures with longitudinal ridge; P^b between P^1 and P^2; P^a slightly nearer to L^1 than to any other seta, lying between L^1 and P^1. Lateral seta (L^1) remote from A^3, on a level with P^1; lateral puncture (L^a) directly posterior to the seta, remote. Ocellar setae (O^1, O^2, O^3) well separated; O^1 equidistant from and ventrad of ocelli II and III; O^2 directly ventrad of and approximate to ocellus I; O^3 remote from and ventrad of O^2, nearer to SO^3 than to O^2; puncture O^a closely approximate to ocellus VI. Subocellar setae (SO^1, SO^2, SO^3) triangularly placed; puncture SO^a equidistant from setae SO^2 and SO^3. Genal puncture (G^a) anterior to seta (G^1).

Labrum (fig. 6, E) with median incision moderately concave; setae M^1, M^2, and M^3 triangularly placed; M^1 and M^2 nearly on a line with La^1; La^1 and La^2 closely approximate; M^3 and La^3 on a line; distance separating M^3 and La^3 about equal to that between M^2 and M^3; puncture equidistant from and slightly back of M^1 and M^2.

Epipharyngeal shield (fig. 6, F) (ES) not sharply defined, merging in a broadly chitinized area on the central forward part of the labrum. Epipharyngeal setae (ET) triangularly grouped, well behind anterior margin of epipharynx, moderately long, narrow, equidistant. Epipharyngeal rods (ER) indicated only by their prominent posterior projections.

Maxillulae normal.

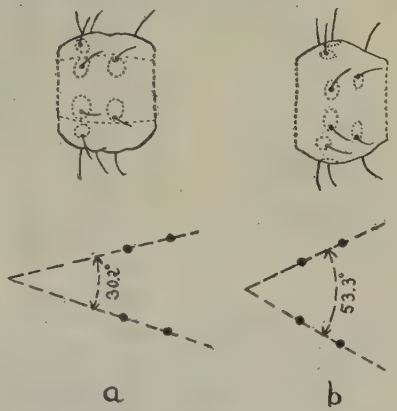

FIG 7.—*a*, Fourth abdominal segment, dorsal view, of larva of sugar-cane moth borer (*Diatraea saccharalis*) and diagram of angle formed by imaginary line through bases of setae; *b*, same for larger cornstalk borer (*Diatraea zeacolella*)

SPECIFIC DESCRIPTION

Summer form (fig. 5, A, C; fig. 6, B): Head slightly trapezoidal in outline viewed from above; widest at the level of the posterior seta P^2; lateral and frontal margins nearly straight; posterior region broad, not constricted; ultraposterior setae of epicranium forming a very obtuse angle, with the apex of the angle pointed to the longitudinal ridge (LR); color rich brown, varying to black at mouth parts and to orange on dorsal aspect. Prothoracic plate pale brown, tinged with black ventrally. Body white. Tubercles light brown or paler. Abdominal tubercles II oval and about twice as far apart as tubercles I. Setae yellow to brown. Imaginary lines connecting setae I and II of abdominal segments 3, 4, and 5 (fig. 7, *a*) on each side, if prolonged, form angles averaging 30.2 degrees. Tubercle I on ninth abdominal segment discernible. Spiracles dark brown. Average length (10 specimens) 25.6 mm.

Winter form (fig. 5, E): Differs from the summer form in the following characters: Color yellow to rich brown, varying to black at mouth parts and to yellow on dorsal aspect. Prothoracic plate yellow. Body tubercles white or pale yellow and not easily distinguished from ground color of body. Spiracles dark brown, distinct and sharply contrasting with rest of body. Average length (10 specimens) 22.4 mm.

As the nearly related species *Diatraea zeacolella* is liable to confusion with *D. saccharalis*, Heinrich has furnished the following descriptions:

SPECIFIC DESCRIPTION OF LARVA OF DIATRAEA ZEACOLELLA

Summer form (fig. 5, B, D; fig. 6, C): Head broadly oval, widest at the level of posterior puncture P^b; the lateral and frontal margins slightly but evenly rounded; posterior region slightly constricted, narrower than middle of head; ultraposterior setae forming a very obtuse angle, with the apex of the angle pointed to the lateral margin. Color yellow, varying to black at mouth parts. Prothoracic plate yellow. Body white. Tubercles dark brown, contrasting sharply with ground color of body. Abdominal tubercles II narrowed and about four times as far apart as tubercles I. Setae yellow to brown. Imaginary lines connecting setae I and II of abdominal segments 3, 4, and 5 (fig. 7, *b*) on each side, if prolonged, form angles averaging 53.3 degrees. Tubercle I of ninth segment not discernible. Spiracles black. Average length (three specimens) 25.2 mm.

Winter form (fig. 5, F): Differs from summer form in the following characters: Body tubercles white or pale yellow and not easily distinguished from ground color of body. Spiracles black, very distinct, and sharply contrasting with rest of body. Average length (4 specimens) 24.5 mm.

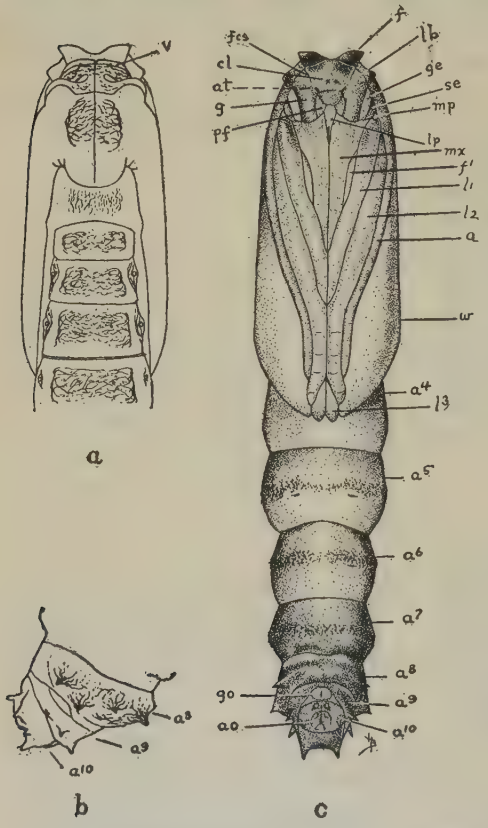

FIG. 8.—Pupa of sugar-cane moth borer; *a*, Dorsal view of anterior portions; *b*, lateral view of anal segments; *c*, ventral view of entire pupa

THE PUPA

On molting for the last time the larva enters the pupal stage, the quiescent period of the insect. The pupa (fig. 8) at first is white, but soon changes to dark brown. It is cylindrical in form and bears little resemblance to either the larva or the moth. The following technical description has been written by Heinrich:

GENERAL CHARACTERS

Elongate; slender, pilifers well developed; maxillary palpi present; prothoracic and mesothoracic legs not extending cephalad between sculptured eyepiece and antenna; sculptured and glazed eyes, labrum, frontoclypeal suture, and invaginations for anterior arms of tentorium clearly indicated; front extending upward into two hornlike projections; maxillæ prominent, only half the length of the wings; wings extending to midventer of fourth abdominal segment; mesothoracic legs not extending to end of wings; metathoracic legs extending to, or a trifle beyond, tips of wings; femora of prothoracic legs clearly indicated; antennæ not reaching tips of wings; body roughened but without hocks or prominent setæ; cremaster absent; posterior end broad; tubercles of the eighth, ninth, and tenth segments developed into stout, sharp, thornlike projections; dorsum of prothorax, mesothorax, and metathorax and the first nine abdominal segments rugosely scobinate; on segments 5, 6, 7, and 8 of the

abdomen the scobinations form a median band encircling each segment; a deep furrow on dorsum separating ninth and tenth abdominal segments; genital opening single and slitlike in both sexes; anal opening a slit terminating in two short lines (人); spiracles elongate, oval, moderate, easily distinguishable.

SPECIFIC DESCRIPTION

From 16 to 20 mm. long; yellow or yellowish brown, darkest at caudal and cephalic ends; the front, clypeus, scobinate areas, and enlarged abdominal

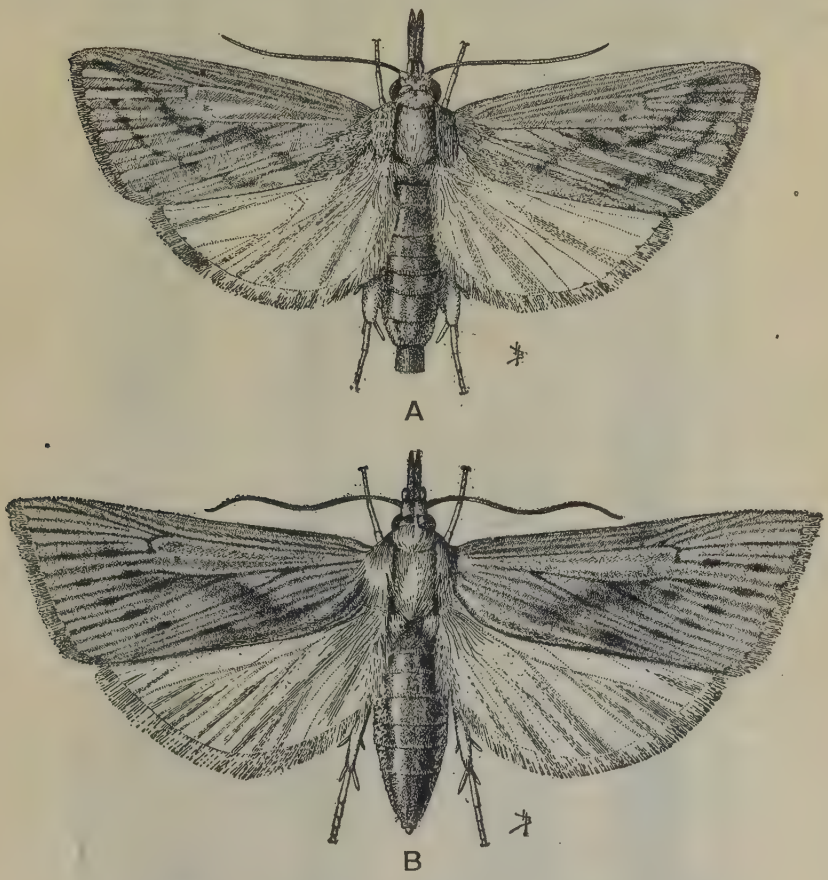

FIG. 9.—The sugar-cane moth borer (*Diatraea saccharalis*): A, Adult male; B, adult female

tubercles dark brown, in some specimens almost black; thornlike tubercles of abdominal segments 8, 9, and 10 stout and very prominent.

THE ADULT

The adult (figs. 9 and 11) is a straw-colored moth, the forewings marked with darker lines. It varies in size, average specimens measuring about an inch across the wings.

FIG. 10.—Mature stalks sugar cane, showing emergence holes of moth borer; A, Variety Louisiana purple; B, variety D 74

In their paper on "The American Moths of the Genus Diatraea and Allies" (*8*) Dyar and Heinrich describe the moth as follows:

Size variable. Forewing yellowish brown, frequently more brown than yellow, especially in the male; lines generally distinct in both sexes, the outer dotted, the inner bent, parallel; discal dot and terminal dots blackish. Hind wing sordid brownish in the male, white in the female. Front gently bulging, without tubercle. Hind tibia of male with a slight whitish tuft of hairs.

Expanse.—Male, 18–28 mm.; female, 27–39 mm.

Male genitalia with lateral lobes rising from above base of tegumen; lobes broad and rounded (nearly as broad as long). Harpe with a densely scobinate

FIG. 11.—The sugar-cane moth borer; adult with wings folded

knoblike projection from base of costa. Uncus with apex pointed. Gnathos strongly spined for half its length from apex. Lateral arms of anellus with a few faint scattered scobinations near their apices, otherwise simple; moderately long. Penis with a single strong cornutus. Figured from reared specimen from Baton Rouge, La.

Female genitalia with a saucerlike chitinous depression on each side of genital opening, roughened above and fusing beneath to form a centrally and irregularly excavated shield in front of genital opening. Ductus bursae broad and chitinized. Bursa moderately large, about as broad as long. Figured from reared specimen from Audubon Park, La.

Abdomen of male with a pair of hair tufts on second segment.

Well distributed throughout tropical America from the Gulf coast of United States to Mexico and Argentina, including the Antilles. We are unable to distinguish any racial forms.

INSECTARY METHODS

Experiments with the sugar-cane moth borer were conducted at New Orleans in a room open on all sides, wire screen taking the place of walls and allowing free access of air and moisture.

Cylindrical cages of wire screen were used for the adults. Shortly after emergence the moths were transferred to these cages, which were made by sewing together with wire the edges of pieces of ordinary window screen to form cages about 7 inches high by 6 inches wide. Some of the horizontal strands of wire were pulled off the top, and pieces of cheesecloth were stretched across so that the exposed ends of the vertical wires would extend through the cloth, thus holding it firmly in place. These cages were placed over saucers of damp sand, and the adults were supplied with young cane or corn leaves in tubes of water for oviposition. The females laid eggs readily on the leaves and also on the sand and the sides and tops of the cages.

The leaves with the masses of eggs were then transferred to specimen jars about 3½ inches wide by 12 inches high, covered with cheesecloth. When the larvae emerged fresh food was supplied as needed, and they were allowed to remain until after the first molt, when they were transferred to individual tubes. These were about half an inch in diameter by 7 inches long, and were made by breaking ordinary glass tubing. One larva, with pieces of fresh stalks of cane or other food plants, was placed in each tube, the ends of which were firmly plugged with cotton batting. A number of tubes were placed in a cigar box, the dark interior of which simulated the interior of a cane plant. The actions of the larvae were readily observable through the glass. The tubes were very easily cleaned by forcing a wad of cotton through them from end to end with a rounded stick or plunger.

The pupae were placed on damp sand under ordinary drinking glasses.

The temperature and humidity apparatus used in the experiments were maximum and minimum thermometers, sling psychrometer, and hygrothermograph.

LIFE HISTORY

MOTH

EMERGENCE

The moth, or adult, emerges from the pupa, which is in a stalk of cane, corn, or other food plant, easily breaking the threads of silk spun by the larva in the tunnel, and forcing its way through the side of the stalk by breaking a thin membrane of plant tissue left by the larva for its ready emergence when it should reach the adult stage. The emergence holes are shown in Figure 10. On emerging the wings are still close to the body, and the moth rests on a convenient leaf or stalk for some time to allow them to expand.

PROTECTIVE HABITS

An adult of the moth borer is very seldom seen, even in the fields of an infested plantation. The moths fly at night and hide among the corn or cane leaves in the daytime, moving only if disturbed. As they are small and of a light-brown color, similar to the dead leaves of cane or corn, they are not readily observed at any time.

The eggs, which are deposited on the leaves of food plants, blend with the leaves and can be found only with difficulty. The entire pupal period, and most of the larval period, is spent in the burrows formed in the stalks, and in this protected situation the borers are safe from birds and most predacious insects.

FERTILIZATION

The mating of the moths undoubtedly occurs at night, but it has not been observed by the writers. Pairs of moths were placed in small cages made of wire screen and cheesecloth and examined during the evening and at intervals through the night, but the moths were never found in copula. Examinations were begun as early as 5.40 p. m., and were continued on one night at short intervals until 11.20 p. m., with three more observations at 2.50, 3.05, and 5.45 a. m. On another night examinations were made at 5.40, 6.40, and 9 p. m., at 11.45 p. m. to 12.30 a. m. (continuously), at 1.35 to 1.50 a. m. (continuously), and at 2.15, 3.50, and 7.15 a. m.

OVIPOSITION

In ovipositing the female stands on a leaf with the head upward. She feels about on the leaf with the extended ovipositor and then deposits one egg, pressing it down and flattening it against the leaf with the end of her ovipositor, the egg adhering to the leaf like a tiny fish scale. Then she moves the ovipositor down or to one side, and another egg is deposited, part of it extending over a portion of the surface of the first egg. More eggs are deposited in the same way. the female gradually moving downward and backward, so that she stands over the slowly enlarging cluster. As the eggs overlap, one being deposited partly over the other, the completed cluster more than ever resembles a group of fish scales. (Fig. 3.)

In this action the moth is very quiet, her wings are folded, antennae back, and legs apart. She keeps the tip of her ovipositor pressed against the leaf continuously, making it difficult for an observer to ascertain the exact time any one egg is deposited. During the action she raises the body "on tiptoe," relaxing and resting against the leaf at intervals. One cluster of 6 eggs was formed in 16½ minutes, and another moth laid 34 eggs in 8 minutes.

Oviposition is begun at dusk and continues throughout the night, the female flying and walking occasionally. Many clusters of different numbers of eggs may be formed in the same night. Individuals deposit eggs during 1, 2, 3, or 4 nights, never longer, according to the writers' records. Oviposition is extended over several nights in cooler weather. Males in the same cage with egg-laying females are indifferent, paying no attention to their mates.

EGG

DURATION OF THE EGG STAGE

The duration of the egg stage has been found to be from 4 to 9 days, depending on the temperature, with the average for the year a trifle over 5 days. These results have been obtained from experiments in the insectary, but it is probable that greater variations between the minimum and the maximum periods occur in the field. The average length of the egg stage at the prevailing temperatures during the different months is shown in Table 3 and is graphically illustrated in Figure 12.

TABLE 3.—*Relationship of mean temperature to the development period of the sugar-cane moth borer in the egg stage*

Average mean temperature (° F.)	Period	Number of records	Average mean temperature (° F.)	Period	Number of records
	Days			*Days*	
72.1	8	1	78.9	6	7
72.4	9	1	81.7	5	41
75.2	7	1	82.8	4	10

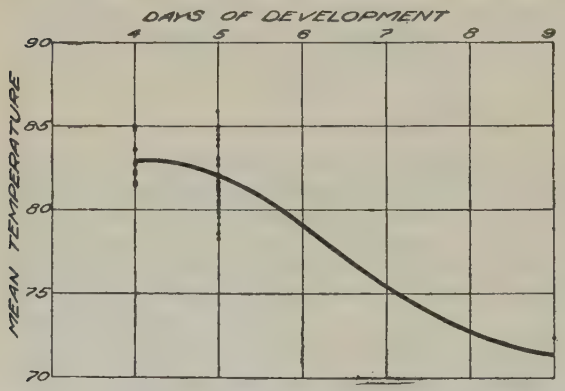

FIG. 12.—Diagram showing relationship of mean temperature to length of egg period of the sugar-cane moth borer and indicating line of calculated means. The dots represent period means of individuals

DEVELOPMENT

When the eggs are first deposited they are creamy white, and in a field of cane are practically invisible against the light green of the cane leaves. They gradually darken until they are reddish brown, with the eyes of the embryo showing through as two small black spots. Later the head turns black, and the eyes can not be distinguished, but the segments of the larva are discernible. The dark head gives to the egg mass a bluish-black cast. Just before hatching the larva can be seen moving within the eggshell.

HATCHING

Hatching usually occurs in the early morning during the summer, and later in the day in cooler weather. Observations indicate that all eggs in a given cluster hatch within a few hours. The larva emerges from the egg by rupturing the upper surface, leaving it torn and ragged but without altering the arrangement or position of the egg in the cluster. The empty eggshells are papery and almost transparent, but they show a slight marking under the microscope. The

cluster of eggshells adheres to the leaf for some time before being washed away by rains, and is more conspicuous at this period than before hatching.

While no definite record has been maintained of the percentage of eggs which hatch, it is only occasionally that one or two in a cluster from a fertilized female fail to produce larvae. Eggs from unfertilized females do not hatch.

LARVA

FOOD HABITS

The larvae are active from the time of emerging and almost immediately begin their search for food. Those from a single group of eggs congregate in the terminal buds of two or three plants in the immediate vicinity of the place where hatched and begin feeding at once. They are active and can move about and lower themselves with silken threads, but they do not seem to travel far. They go well down into the "bud" or whorl of the plant, where they are protected from bright light and from possible enemies, and they suffer no harm if, as is frequently the case, the bud is full of water. Young larvae have often been observed to crawl down into a bud which was completely submerged and feed for several hours under water without any apparent discomfort. Some of them at first eat only the epidermis from one side of the leaf causing a yellowish blotch, but a little later they burrow through the leaves while these are still unrolled. As one leaf is thus pierced in a number of places at once a row of holes arranged horizontally will be seen when it expands. Very often the larvae burrow into the midrib, following a zigzag course for several inches along its length. They can be seen very plainly by holding the infested leaves up to the light. The larvae usually leave the buds or the midribs after the first molt and crawl down between the leaf sheaths and the stalk, some of them entering the stalk immediately and others feeding for a day or two, or until after the second molt. It seems that the larvae feed longer outside the stalks on old cane than on young plants.

The larvae feed either up or down from the place of entrance, but usually upward, producing a winding burrow or tunnel a foot or more up the stalk. The burrows may be branched, or two or more may unite, forming a network of tunnels in a badly infested stalk. The tunnels are quite small at first, but they are enlarged as the larvae increase in size until they are one-eighth to one-fourth inch in diameter, allowing the larvae to move about and turn around with freedom. The frass is packed loosely behind the larvae, seldom completely closing the passages. The burrows usually become infested with the red-rot fungus within a short time, causing the surrounding tissue to turn red, the discoloration often extending for several inches beyond the burrow. (See frontispiece.)

CANNIBALISM

When larvae are confined in cages in the insectary they are cannibalistic, especially in the smaller stages. If 200 or 300 newly hatched larvae are left together they will be reduced to 40 or 50 within two

or three days. The smaller ones are usually eaten by the larger when larvae of different stages are confined together, though full-grown ones also are attacked. It seems that the larvae usually are attacked when they are weak or inactive, especially just before or after molting. Three or four larvae often are found living in the same stalk of cane, but in these cases they are more or less separated by their burrows, and it is not likely that large larvae are eaten by others under field conditions, where they have freedom of action, whereas the habit of small larvae of congregating in the terminal buds of the plants is very conducive to cannibalism, and many doubtless are destroyed by their companions.

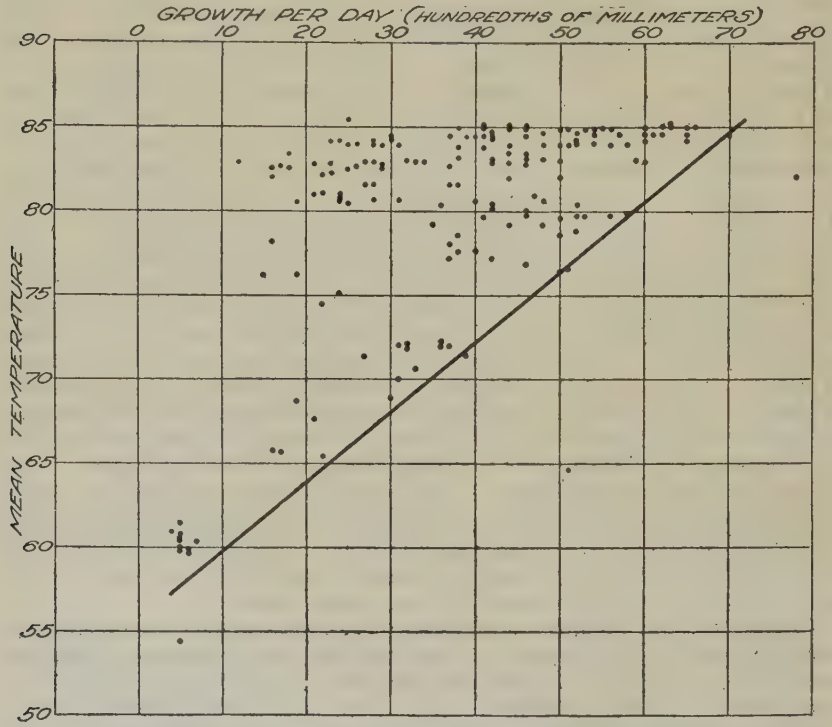

FIG. 13.—Diagram showing relationship of mean temperature to larval growth of the sugar-cane moth borer, per day, in hundredths of millimeters, showing line of maximum growth of normal individuals. The dots represent growth of individuals in hundredths of millimeters

GROWTH

The rate of growth is dependent upon many external conditions, the temperature and kind of food being the most important factors, but larvae feeding under similar conditions show a great variation in the rate of development and in the length of the larval period, as is shown by Figure 13. Under favorable conditions the rate of increase in body length is about 0.75 mm. per day, but it is often much less. Larvae are from 1.5 to 2 mm. long when hatched and from 25 to 30 mm. long when fully grown.

MOLTS

Before molting the larvae stop feeding for several hours and appear stiff and helpless. The skin then ruptures just back of the head, and by a series of contractions and contortions it is worked back over the body. Sometimes the head capsule is cast before the skin and at other times not until afterwards, but usually it is cast during the process of molting. The capsule is worked loose by the movements of the body and is deposited at one side.

The freshly molted larvae are white and almost colorless, or show faintly purplish markings running the length of the body. The head is white and soft when first molted, but it turns mahogany brown in a few hours, and the markings deepen. Rosenfeld and Barber (*27*) say that the color of the protective fluid secreted by the larvae is determined by the color of the head and that the fluid is white in freshly molted larvae.

The whole process of ecdysis requires about 15 minutes. The larvae then turn, eat the discarded skin, and recommence feeding on the cane.

Ordinarily there are 5 molts, but sometimes there are only 4 in rapidly developing larvae. More than 5 are fairly common, as many as 14 having been observed in hibernating larvae. When the larval period is prolonged by low temperature or other conditions, the larvae continue molting, with little or no increase, or even a decrease, in size.

INSTARS

The period from emergence until the first molt is called the first instar. Between the first and second molts the period is known as the second instar, and so on until the larva reaches the pupal stage. The last instar is the period between the last larval molt and the beginning of the pupal period. The number of instars has been found to be from 3 to 10, with 5 as the most common number. The number in relation to mean temperature is shown in Table 4.

TABLE 4.—*Relationship of mean temperature to the number of instars of the larva of the sugar-cane moth borer*

Average mean temperature (° F.)	Number of instars	Number of records	Average mean temperature (° F.)	Number of instars	Number of records
65.5	10	4	78.9	7	18
68.8	9	8	80.3	4	65
69.8	8	11	81.1	5	102
74.8	3	14	82.2	6	50

DURATION OF LARVAL PERIOD

The larval period is the most variable of all the stages in the life history of this insect, as it is this stage which is prolonged by hibernation or adverse conditions. The first molt takes place from 3 to 6 days after emergence, when the larvae are from 2 to 4 mm. long. From 4 to 8 days are spent in the second instar, and during this period the larvae attain a length of from 6 to 9 mm. The third instar is somewhat longer and requires from 6 to 9 days, the larvae

reaching 10 to 15 mm. in length, while the fourth instar lasts from 4 to 6 days, at the end of which the larvae are 15 to 20 mm. long. From 3 to 6 days are spent in the fifth instar, and the larvae attain a length of from 20 to 30 mm.

The usual time required for the larval stage under favorable conditions is from 25 to 30 days in summer and from 30 to 35 days in the cooler weather, but it may be much longer. Larvae from the same mass of eggs and reared under exactly the same conditions vary a great deal, and some of them require two or three times as long as others to pupate. Under the most favorable conditions the larval period has been as short as 18 days, and has varied from this to 276 days for hibernating larvae. The larvae are very adaptable in this way and can pass over periods of cold or food shortage without serious inconvenience. Typical life histories at different seasons of the year are shown in Table 5 and Figure 14.

TABLE 5.—*Relationship of mean temperature to developmental period in larval stage of the sugar-cane moth borer*

Mean temperature (° F.)	Average period	Number of records	Mean temperature (° F.)	Average period	Number of records	Mean temperature (° F.)	Average period	Number of records
	Days			*Days*			*Days*	
59.4	246.5	2	75.1	54	2	81.5	35.1	7
59.6	216	2	75.4	33	1	81.7	46	1
59.8	232.5	5	76.1	60.3	2	82	50	2
60	221	1	76.2	66	2	82.1	65	1
60.3	225	1	76.3	26	1	82.2	54.5	2
60.4	224	1	76.5	27	1	82.4	52	1
60.5	233	2	76.8	28	1	82.5	57.6	3
60.7	248	1	77.1	32	2	82.6	42.5	6
60.9	262	1	77.2	38	2	82.7	40.4	5
61.4	242	1	77.5	31	1	82.8	36	12
65.3	63	1	78	34	1	82.9	31.1	19
65.6	76	1	78.1	71	1	83	24.3	6
65.7	74	1	78.2	28	3	83.1	31	1
67.6	65	1	78.3	48	1	83.3	71	1
68.7	56	1	78.5	22	1	83.4	34	1
68.8	52	1	78.7	25	1	83.7	34	2
70	45	1	79.1	42	4	83.8	32.8	7
70.6	39	1	79.5	24	1	83.9	38.8	10
70.8	34	1	79.6	29	1	84	24	3
71.4	33	1	79.7	26	1	84.1	45.5	4
71.7	35	1	79.8	23.5	2	84.2	29.7	8
71.9	37	1	79.9	23	1	84.3	38.5	2
72	38	2	80	28	1	84.4	29.6	9
72.1	38.5	2	80.1	33	1	84.5	20.5	9
72.2	22	1	80.3	48.5	2	84.6	25.5	5
72.3	37	2	80.4	31	1	84.8	25.5	2
72.9	24	1	80.5	57	3	84.9	26.2	13
73.3	25.8	5	80.6	38	1	85	25	8
73.5	27	1	80.7	49	1	85.1	19	1
73.9	28	1	80.8	42	1	85.4	54	1
74	39	1	80.9	46	1			
74.4	49	2	81	45	2			

PUPAL CELLS

When the larvae are fully grown they construct a kind of pupal cell before pupating. The larval tunnel is cleaned, enlarged, and extended to the rind of the cane, where a small circular opening 4 to 5 mm. in diameter is made. The rind is not completely cut out, but it is eaten away from the inside until only a thin paperlike section, lightly attached at the edges, remains. This is held in place by threads of silk fastened to the inside so that the moth can easily

escape, but other insects can not enter. The lower end of the cell is closed with frass and silk, and the whole cell is lightly lined with silk. In the rearing tubes in the insectary the pupal cell usually is formed on the side of the cane between it and the sides of the glass.

PREPUPA

As the pupal cell nears completion the larva merges into the prepupal stage. No molt occurs, but the larva ceases feeding and becomes sluggish and helpless. The body contracts longitudinally, especially the thorax, while the use of the legs is lost and the insect thrashes about as do the pupae. From one to three days are spent in the prepupal stage, but it often happens that this stage is not noticed by an observer, as it is not very distinct from the larva stage.

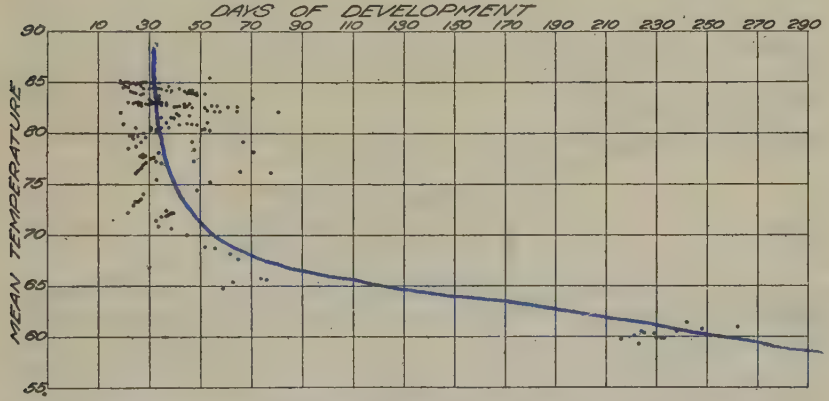

FIG. 14.—Diagram showing relationship of mean temperature to length of larval period of the sugar-cane moth borer. The dots represent period means of individuals

PUPATION

After resting for a short time as a prepupa the pupa is disclosed by the casting of the last larval skin in the same manner as the others are cast.

PUPA

The pupa at first is dirty white, about the same color as the hibernating larva, with faint purplish longitudinal stripes. It gradually hardens and darkens, and in an hour or two becomes mahogany brown. As the time for emergence approaches the pupa darkens more and may become almost black.

ACTIVITY

The pupa is very active when disturbed, being able to thrash about with its abdomen, which gives it a rolling, squirming motion. A touch or a jar will cause this action, as will also the placing of the pupa in direct sunlight in summer. Placed in the sun, a pupa squirmed about till it reached a shady place.

DURATION OF PUPAL PERIOD

The first pupae in the spring are formed from overwintering larvae in April or May, and pupae may be found from this date to December. Few larvae pupate after the middle of November, those which have not pupated prior to this time hibernating as larvae. Nearly 200 larvae were collected in cane cut for the mill from December 2 to 4, 1915, but no pupae were found in all the stalks cut open. Adults have emerged from pupae in the insectary as late as December 5, but a large percentage of those which did not pupate until late and had the pupal period prolonged by cold did not emerge.

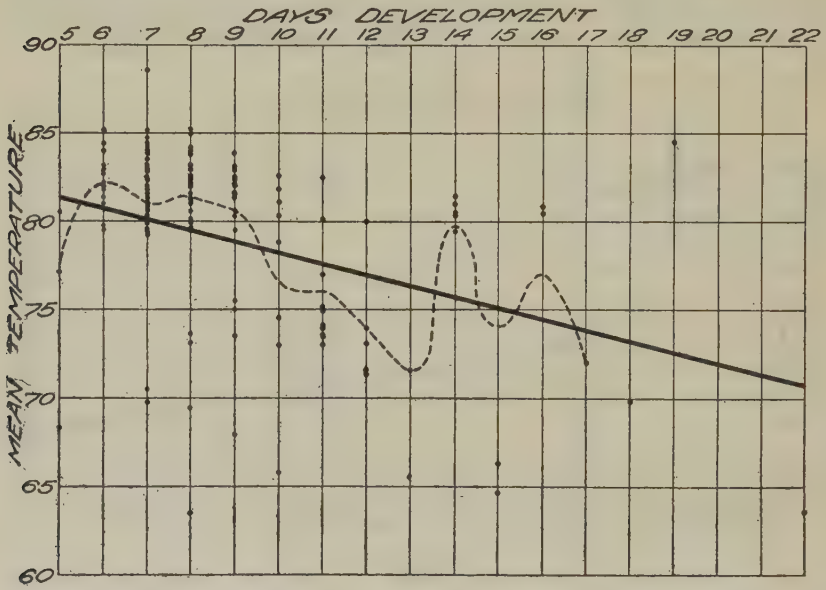

FIG. 15. Diagram showing relationship of mean temperature to length of pupal period of the sugar-cane moth borer and showing line of calculated means (dashes) and general trend of means (solid line). The dots represent period means of individuals

The pupal period, like the larval, has a wide variation, from 6 to 22 days being required for the emergence of the adult, with an average of 8.5 days throughout the year. The pupae which produced male moths required on an average 8.8 days for emergence, and those which produced females 8.4 days. Often there is a variation of 2 to 3 days among pupae which transform on the same date. The data are presented in Table 6 and Figure 15.

LONGEVITY OF ADULT

Limited observations made in September, 1925, show that adults subjected to an average mean temperature of 82.9° F. live from 3 to 8 days, the average being 4.7 days.

TABLE 6.—*Relationship of mean temperature to the development period in the pupal stage of the sugar-cane moth borer*

Average mean temperature (° F.)	Period	Number of records	Average mean temperature (° F.)	Period	Number of records	Average mean temperature (° F.)	Period	Number of records
	Days			*Days*			*Days*	
63.7	22	1	76.1	11	12	80.9	9	42
69.8	18	1	76.6	10	19	81.1	7	153
71.6	13	1	77	16	5	81.3	8	92
72	17	1	77.1	5	3	82.3	6	27
73.9	15	5	79.7	14	7	84.6	19	3
74	12	4						

DURATION OF THE LIFE CYCLE

The length of the life cycle varies considerably with the temperature. Taking the minimum of each immature stage the sum of 28 days is obtained, while in the same way a maximum of 293 days is secured. The sum of the periods required by most individuals in the various stages is 43.1 days, which may be regarded as an average. The maximum larval period recorded was 262 days and included hibernation.

SEASONAL HISTORY

SEASONAL ABUNDANCE

NUMBER OF BROODS OR GENERATIONS

The variation in the time required for the development of the moth borer is so great that there are no distinct broods or generations. It is found that some larvae require three or four times as long to reach the adult stage as others hatching from eggs laid at the same time, and this causes such an overlapping that the broods can not be distinguished. (Fig. 16.)

The time of emergence of moths in the spring varies from year to year, depending on the season. The season of 1922 was very early, eggs, "dead hearts" in sugar cane, and corn plants killed by the borer being found at New Orleans on April 15. In general, however, the first moths seem to emerge during the latter part of April.

In 1914 the first emergence in the insectary was not until May 8, and emergences continued until May 25. Adults emerged from cane planted in boxes of soil as late as June 21. A pupa from the spring brood of borers was found in a "dead heart" on June 2, 1914. Thus adults from the hibernating larvae and adults from the first spring generation are emerging at the same time. This overlapping continues until by midsummer the broods can not be separated.

The maximum number of generations may be computed by taking the first eggs laid by each generation and assuming that they would develop under most favorable conditions, thus reaching the adult stage in the shortest time possible at the prevailing temperature:

The first eggs in the spring, laid by adults from the hibernating larvae, would ordinarily hatch by May 1, and the adults would appear by June 10.

Adults of the first generation would lay eggs June 11, and these would produce adults on July 24, after 43 days.

Adults of the second generation would lay eggs on July 25, and these would produce adults on September 1, after 38 days.

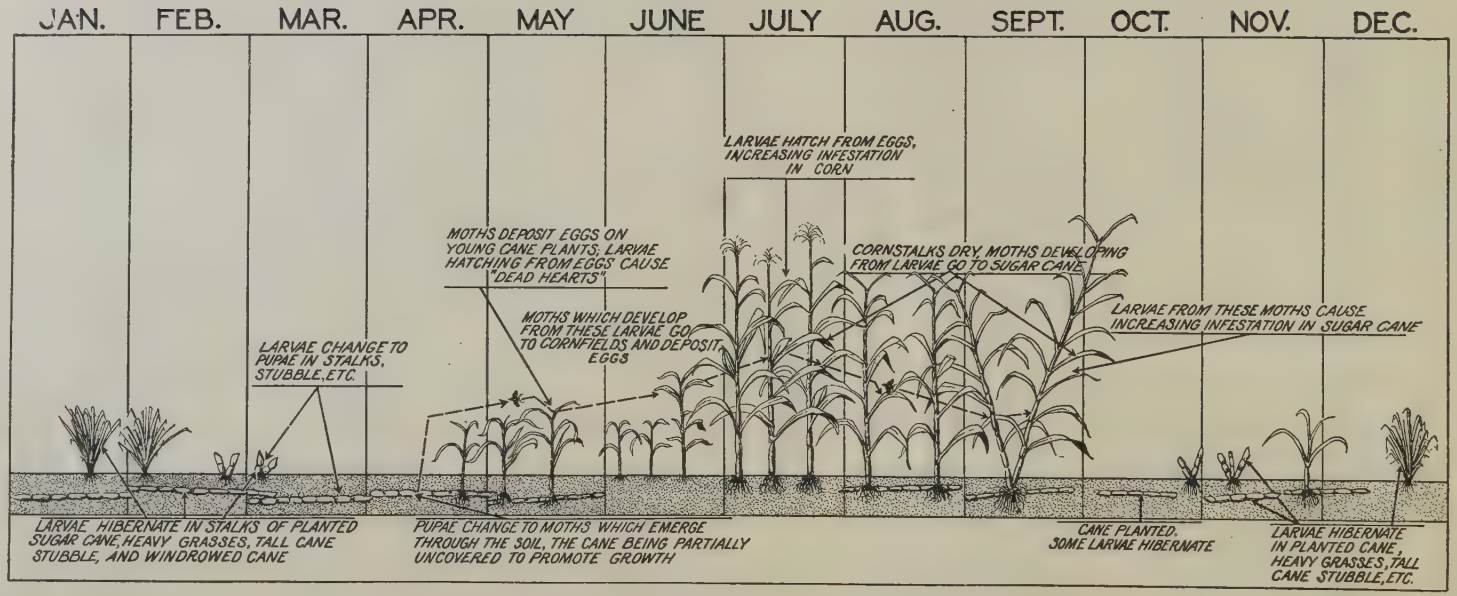

FIG. 16.—Seasonal history of the sugar-cane moth borer

Adults of the third generation would lay eggs September 2, and these would produce adults on October 8, after 36 days.

Adults of the fourth generation would lay eggs on October 9, and these would produce adults on November 18, after 40 days.

Adults of the fifth generation would lay eggs on November 19, and the larvae would hibernate and emerge in the spring.

On the other hand, it is equally possbile for two generations to span the entire year, if we take the last to emerge from hibernation and allow them the maximum time for completing their life cycle. The latest record of emergence is June 21, 1914, and a moth emerging then would not oviposit before June 22 or 23. Some eggs laid in the insectary June 25, 1914, required 90 days to complete their cycle, the adults not emerging until September 23. Larvae hatching the latter part of August or in September frequently hibernate, so it is evident that the whole year could easily be taken up by two generations.

These data are based on rearing notes in the insectary and on observations in the field. While first-instar larvae have been found in the fields from May 5 to the middle of December, and adults have emerged in the insectary in December, it is seldom that the maximum number of generations are produced in the field. Most of the larvae reared in the insectary have required from one and a half to two or more times the minimum length of time necessary to complete their life cycle, and there are usually only four, seldom five, generations. If the spring is early and other conditions are favorable, there may be five generations, but if the spring is late and cold there will be only four.

POSSIBLE ANNUAL PROGENY OF ONE PAIR

It is on account of its rapid rate of reproduction that the borer is able to inflict enormous damage. As many of the larvae are killed in the fall by the grinding of the cane, and as there is a high mortality among those which escape and hibernate, it is evident that comparatively few emerge in the spring. Yet there is always a heavy infestation by fall. The rapidity of reproduction during the warm months is the only factor which can account for this high infestation.

The record of oviposition for 56 moths at various times during the season of activity shows that each female moth deposits on an average 210 eggs. The sexes are produced in equal proportions. Allowing 200 eggs for each female and four generations a year as a conservative estimate, it is found that each pair surviving the winter is capable of producing the following numbers:

Generation	Borers
First	200
Second	20,000
Third	2,000,000
Fourth	200,000,000
Total	202,020,200

Of course this maximum number will never be produced, because of the numerous checks which control the insect, but something of its magnitude may be realized by considering that if the offspring of one female were confined to 1 acre there would be over 10,000

borers per stalk of cane, about 20,000 stalks being the average per acre. Under average conditions about 50 per cent of the stalks are infested and about 25 to 30 per cent of the infested stalks contain borers when cut for the mill, giving from 2,500 to 3,000 borers per acre. Considering the possibilities, it is only surprising that the infestation is not much higher.

PROGRESS OF INFESTATION

The moth borer is late in developing in the spring, and not much injury can be found through the summer, but the numbers of borers gradually increase. When the cornstalks become dry in July and August the emerging moths undoubtedly migrate to sugar-cane fields in large numbers. The infestation increases rapidly from about this time until the cane is cut for grinding.

VARIATIONS IN INFESTATIONS

The infestation of different fields during different years may vary from a low percentage to 100 per cent, that is, every stalk may be bored. In an extreme infestation nearly every stalk will be bored several times and tunneled from end to end.

On the whole, plant cane appears to be more heavily infested than stubble cane. The reason for this is probably that the infestation largely starts in plant cane, the moths emerging in the spring from the planted stalks. During the long growing season, however, the moths fly from field to field, and the infestation becomes more uniform as the season advances. The borer can live over in stubble, however, and the cane cut so that tall stubble is left affords an ideal hibernating place. It has been found that a heavy infestation can be carried over from one year to another by the borers in the stubble.

It seems rather doubtful whether one of the commonly planted varieties is more resistant to the borer than another. It is claimed that the canes brought from Java, which go under the names of P. O. J. 36, P. O. J. 234, etc., are comparatively resistant.

Cane grown on sandy land is said to be more heavily infested than cane grown on heavy soil. If so, this may be due to the greater ease with which the moths emerge from light soil.

Fertilizers, especially barnyard manure, are popularly supposed to increase the infestation. In the opinion of the writers, fertilizers can do so only by promoting an early and rapid growth of the cane, thus attracting egg-laying moths to the fertilized fields and away from fields which, having small plants of a poor stand, are not so attractive.

The heaviest-growing cane is always the worst infested. This is undoubtedly due to the attraction it has for the flying moths. The moth seeks a dark hiding place in the daytime, and such places are easiest found in the healthiest and densest fields.

It has been observed that the fronts of Louisiana plantations are more badly infested than the rear. It must be explained that the "fronts" are close to a river or a bayou, and consist of the best-drained land. The land slopes back to a swamp, and the back land is often badly drained. There may be two reasons for the fact that the heaviest infestation is at the front. One is that the cane is better, and the other is that on account of the drainage the larvae hiber-

nating in the planted cane or stubble are not drowned, whereas in the rear, water often remains on the cane long enough to kill the larvae within.

Small fields of sugar cane completely surrounded by cornfields have been found to be more seriously infested than fields more isolated from corn.

MANY LARVAE CRUSHED IN THE MILL

The greater number of moth borers in the larva stage in the late fall and early winter, which would otherwise hibernate, remain in the stalks of cane after they are cut. When the stalks are ground in the mill these larvae are crushed with the cane, and only such borers as may be in the stubble, seed cane, scraps of cane left about the plantations, and Johnson grass, and other grasses are left to start the infestation the following year. Because the species is so prolific, it is easily possible for a very few borers which remain alive in the spring to cause a high infestation over a whole plantation by the following grinding season.

NATURAL DISSEMINATION

Owing to the habit of the moths of hiding in the daytime and flying at night, it is difficult to determine directly whether the area infested is extended by their flight. At a point on the northern edge of an infestation, which happened to be under observation, there was no outward extension for several years, though the northern limit is now far beyond this point.

The moths become active at dusk, and judging from their rapid movements they are strong fliers. Occasionally moths have been captured at a distance of at least half a mile from food plants, and it seems likely that they can fly much farther. Though an individual moth might be limited in flight, it is possible for the area infested during a year to be greatly enlarged by flights of successive broods during the season.

ARTIFICIAL DISSEMINATION

The infestation of much new territory is probably through shipments of sugar cane, both for grinding and planting. The mature canes, if infested, contain larvae or pupae or both, and if left in a freight car on a railway siding, or if planted and imperfectly covered, the resulting moths can easily emerge. It is then an easy matter for the species to become established on such food plants as may be available at the time of year, and the infestation of adjacent cane fields may be expected within the next few years.

Infested seed cane was planted about 1909 above Baton Rouge on property which had previously been devoted to cotton farming and undoubtedly was not infested by the moth borer. In 1914 practically every stalk of cane was bored.

Introduction of new varieties of sugar cane should be left to experiment stations, and the cuttings should be subjected to special treatment and inspection.

If cane is needed for planting or grinding by persons outside the infested area, great care should be taken to secure uninfested cane. Freight cars used for hauling cane may contain infested scraps which should be collected and destroyed at frequent intervals.

HIBERNATION

STAGE OF INSECT THAT HIBERNATES

The moth borer passes the winter in the larval stage. As fall approaches some of the larvae go into hibernation, while others enter the pupal stage and emerge shortly as moths. There is nothing to indicate which will hibernate and which will become moths. During the summer of 1913 some of the larvae from eggs laid as early as August 13 went in hibernation, while others from the same mass of eggs completed their development as usual. Other larvae from eggs laid August 18 and September 8, 22, and 27 died or hibernated, but larvae from eggs laid September 1 and 18 completed their development and emerged in October and November. One adult emerged in December from eggs laid as late as September 25, although the others from this mass of eggs hibernated. In general, it seems that most of the larvae from eggs laid after the middle of September hibernate if they are not killed in the mill, but this depends somewhat on the season, as more will develop in a late fall. All instars of the larvae hibernate. Small first and second instar larvae have been seen as late as the middle of December crawling over the cane tops, and these would hibernate if they found suitable places. Hibernation is not what may be called complete, since the larvae become active on warm days and continue to feed to some extent. When infested cane is windrowed in the fall it is often badly damaged by the borers continuing their feeding throughout the winter, destroying many eyes and tunneling the stalks until they become brittle and break with handling. The well-grown larvae continue molting at irregular intervals throughout the winter, but do not increase in size; in fact, they are even smaller and more flabby in the spring than they are in the fall. The small larvae increase slowly in size, and all hibernated larvae are of a very uniform size in the spring.

PLACES OF HIBERNATION

The larvae hibernate in scraps of cane, stalks of large grass, cane stubble, and planted and windrowed cane. A few larvae in Texas have been found in cornstalks during the winter, but these stalks dry out and become unattractive to the moth borer long before cold weather begins. The usual place of hibernation of the closely related species *D. zeacolella*, however, is in the taproots of corn.

The favorite places of hibernation are scraps of cane left after grinding, and windrowed and planted cane. The windrow forms an ideal place for hibernation, the larvae being well protected by the earth and the quantity of leaves covering the stalks.

It is evident that the planted cane is a source of serious infestation, and it is also evident that the infestation in a field can be carried over in the sugar-cane stubble. At the present time nothing can be suggested for destroying the borers in the stubble, but such a remedy is unnecessary if the cane is cut so close to the ground that the knife will pass below the borer tunnel, thus leaving no borers in the remaining stubble. More uniform and lower cutting is obtained by mechanical means than by handwork. For planted seed cane there are treatments of the cane in heated water and water of ordinary temperatures. It is possible that continued and general

treatments of seed cane would so greatly reduce the infestation on a plantation that in a few years it would be only slight. The writers have not had an opportunity of giving this an adequate test.

EMERGENCE FROM HIBERNATION

The hibernating larvae pupate in the spring and emerge as moths when the cane is from a few inches to a foot or more in height. Moths have been found emerging from cane under one-half inch of packed soil, so that it is often possible for them to emerge from planted cane. There is of course no obstacle to their emergence from grass or cane stubble.

SURVIVAL OF HIBERNATED LARVAE

Only a small proportion of the larvae which go into hibernation survive the winter and emerge as adults. They die from time to time during the winter, and those which have been in the larval stage for a long time seem to have trouble in pupating and often die in the attempt. Then, too, the mortality is higher among the pupae from hibernated larvae than from others, and the adults that emerge are not so vigorous.

Not more than 10 per cent of the larvae kept under insectary conditions emerged, and as those pupating in the field often have the additional trouble of emerging through some depth of soil, it is evident that only a small percentage survives. On account of their rapid increase in numbers it requires only a few moths in the spring to produce a large number of borers during the summer and fall.

LONGEVITY OF HIBERNATED LARVAE

The usual larval period is greatly prolonged by cold weather or other adverse conditions, and the larvae can survive great hardships. It is not at all uncommon for them to live for a month or two without food, and Stubbs and Morgan (*29*, *p. 908*) have kept them for 75 days without food and had them pupate afterwards. Rosenfeld and Barber (*27*, *p. 276*) kept a larva for 200 days without food, and it pupated, while E. R. Barber, in unpublished notes of the Bureau of Entomology, records placing a larva in the photographic dark room on October 19, and finding it alive June 9, a period of 231 days, during which it did not feed on the piece of sugar cane provided. The larva stage of overwintering individuals is generally about 7 or 8 months, and during this time there are 10 or 12 molts, but in the authors' experiments some required 276 days and 14 molts to reach the pupa stage.

NATURAL CONTROL

CLIMATIC CONTROL

EFFECT OF RAINFALL

Wolcott (*33*, *p. 2*, *4*, *6*), while entomologist of the Insular Experiment Station, Rio Piedras, Porto Rico, made a number of observations which tend to prove that the moth borer is adversely affected

by rainfall. The following is an abstract of Mr. Wolcott's conclusions:

A large number of careful observations made in Porto Rico during the past grinding season, confirmed by the evidence from other countries, indicates that there is a constant relation between the amount of rainfall and the abundance of Diatraea. The table, which gives the percentage of infestation of cane by Diatraea in conjunction with the total annual rainfall in inches for 1914, shows that the abundance of Diatraea is in inverse proportion to the amount of rainfall. (The table mentioned shows that the infestation varies from 6 per cent, where there were 101 inches of rain, to 66 per cent, where there were only 21 inches.) . . .

It is comparatively easy to demonstrate the effect of an abundance of rainfall in lessening the numbers of Diatraea, but much more difficult satisfactorily to account for this effect. The eggs of the borer are deposited on the leaves of the cane, and when the young larvae hatch, a considerable interval elapses while they crawl about on the cane before they enter the stalk or the midrib of the leaf. It is quite probable that this is one of the most crucial periods in its life history, and that considerable numbers of borer larvae were killed in young cane by the more rapid growth of the central shoot of a cane plant than of the outer leaves. Also, larvae were found which had been drowned in a mixture of water and decaying cane juices which had collected in their tunnels after rains. To avoid danger from these causes, many larvae were found living outside the shoot, where they were exposed to the attacks of predators or parasites.

The rainfall over the sugar belt of Louisiana does not vary to any great extent, and while there are annual differences both in infestation and rainfall at various points, a careful study of the subject has failed to prove that these variations correspond as they do in Porto Rico.

McDonald (*23*) of the New Orleans office of the Weather Bureau has recently found that it is the winter and early spring rains which apparently go far in determining the infestation of the moth borer for the subsequent growing season. Mr. McDonald writes:

Examination of the weather conditions in the years of highest losses as compared with years of lighter infestation pointed to the rainfall as showing some correlative fluctuation. The rainfall over winter appeared to show greatest similarity of variation, and the period from November through the following April was chosen as that offering the highest correspondence. While the series of only 13 years is a very brief period for mathematical correlation, Table 15 [7] strongly suggests the existence of a high inverse relation, the season of lighter rainfall accompanying heavier than average losses from cane borer infestation in five out of six years, and excess of rain pairing with lighter than average losses in six out of seven years. The value of the correlation coefficient computed from these data is —0.86 (±.05), a value so highly significant as to seem conclusive of a large and definite relation between rainfall and cane borer losses.

TABLE 7.—*Relation of rainfall to cane-borer infestation, cited from W. F. McDonald (23, p. 32)*

Year	Percentage of loss due to borer	Difference from average percentage	Rainfall departure, November to April	Year	Percentage of loss due to borer	Difference from average percentage	Rainfall departure, November to April
			Inches				*Inches*
1912	15	−5	+6.4	1919	9	−11	+11.2
1913	17	−3	+5.1	1920	19	−1	+1.9
1914	26	+6	−1.3	1921	25	+5	−0.3
1915	24	+4	−0.1	1922	17	−3	+3.7
1916	30	+10	−9.9	1923	23	+3	+2.9
1917	18	−2	−2.5	1924	13	−7	+4.9
1918	21	+1	−4.3				

The estimates of loss were supplied by the writers. In a footnote Mr. McDonald adds:

> The loss percentage from cane borer in 1925, which has been published since this was written, is computed at 30 per cent, following the extraordinary drought affecting the sugar region during the autumn of 1924 and spring of 1925. A rainfall deficiency of about 8 inches was accumulated from November, 1924, through April, 1925, although the drought was of much longer duration. These figures thus bear out the inverse relation revealed by the data from 1912 through 1924.

The writers believe that the borer is adversely affected by a wet winter and spring, for the reason that the hibernating larvae in the seed cane and the stubble are destroyed by water standing on the fields for rather long periods. This is in accord with what is known concerning the effect of floods and the effect of immersing infested cane in water.

EFFECT OF FLOODS

Complete flooding of cane fields for long periods seems to have a great influence on the infestation of the moth borer. For four years observations have been made on a plantation near Morgan City, which was under water for some weeks in the spring of 1912. In the fall of 1912 the infestation on this plantation was 4 per cent. In the fall of 1913 it was 6 per cent, only slightly higher than in the year of the overflow. In the fall of 1914, however, the infestation had reached 68 per cent, while in 1915 it was 87 per cent. It seems that the moth borer was much reduced in numbers by flooding, but that the numbers increased rapidly the second year after the inundation.

EFFECT OF IRRIGATION

Though floods seem to reduce the percentage of infestation, it has not been observed that irrigation has any effect. Observations have been made on the nonirrigated plantations of Louisiana and on the irrigated properties of the lower Rio Grande Valley of Texas. No difference in the infestation has been noticed which can be traced to irrigation.

EFFECT OF FREEZING TEMPERATURES

After freezing weather in January, 1924, during which the temperature went as low as 17.5° F., the writers examined planted seed cane, stubble, and pieces of cane lying exposed on the surface of the ground. Larvae were found to be dead in exposed cane and stubble but in planted cane and in tunnels in stubble below the surface of the ground they were alive. The loss of sugar due to the borer in 1923 had been 23 per cent, whereas in 1924, after the freeze, it was only 13 per cent. The rather low infestation along the Mississippi coast, where the fields are scattered, was also greatly reduced.

Although the writers found borers killed by the low temperatures, they realize that the subsequent low infestation was due not only to the cold winter but to an excess of rainfall during the winter months (see "Effect of rainfall," p. 37).

EFFECT OF SOURING CANE

After the extremely heavy borer infestation of 1925, the writers had occasion to examine much badly bored cane which had been windrowed for spring planting. This cane was examined in March, 1926, and at that time it was found that many of the borers in the stalks were dead. The badly bored parts of the stalks were fermenting, and it seemed that the borers had died from the effects of the acids on their bodies, from the decay of their food, or from both causes combined.

It is evident that after extremely heavy damage, this adverse effect on the hibernating larvae tends to reduce the species to its normal numbers.

FUNGOUS DISEASES

Although a fungous disease on the larvae of *Diatraea saccharalis* was studied by Picard[9] at the Louisiana State University in 1903, its occurrence under natural conditions is very rare. Larvae are sometimes attacked by it in the insectary, especially when kept in tin boxes, but all attempts to inoculate healthy larvae have failed, and it is probable that the fungus is only saprophytic. One such diseased larva of *D. zeacolella* sent in by A. G. Davis from Chipley, Fla., was submitted to Alden T. Speare, mycoentomologist of the Bureau of Entomology. He reported that "the fungus seems to be very close to *Aspergillus parasiticus*, which I found to be parasitic upon the sugar-cane mealybug in Hawaii. There is no doubt that the fungus is an Aspergillus, but I would venture no specific name at present. *A. flavus* has been found to be parasitic upon sugar-cane mealybugs in Louisiana and in Porto Rico, but this is the first record to my knowledge of an Aspergillus on Diatraea, hence I can not vouch for its parasitism."

The fungus parasite *Cordyceps barberi* is recorded by Van Dine (*31*) from Porto Rico, and by Bodkin (*3, p. 30*) from British Guiana on both the larva and the pupa of Diatraea. The present writers planned to experiment with this disease, but they were unable to obtain cultures or diseased specimens until through the courtesy of Longfield Smith they received in 1919 live specimens of this fungus from the island of St. Croix. Inoculation experiments were conducted in cooperation with C. W. Edgerton, plant pathologist of the Louisiana State University, but only negative results were obtained.

PARASITES AND PREDACIOUS ENEMIES

MOTH-BORER ENEMIES IN THE UNITED STATES

Four parasites of species of Diatraea have been found in the United States, but three of them are extremely rare. The chalcis-fly *Trichogramma minutum* Riley is universally distributed in the sugar-cane fields of Louisiana and of the lower Rio Grande Valley of Texas, and it is a very important factor in the control of the moth borer. It is a minute wasplike insect, the female of which deposits

[9] PICARD, J. R. NOTES ON SUGAR-CANE BORER FUNGUS. 1903. [Unpublished thesis. Copy on file, Library State Univ. La., Baton Rouge.]

her eggs within the eggs of the borer, in the course of a few days numbers of adult parasites emerging from the moth-borer eggs.

A similar insect is the black parasite *Ufens niger* Ashmead, found near Brownsville, Tex., by the senior writer in 1912. This has not been found a second time, although George N. Wolcott made a special search for it extending over about two months in the summer of 1917. Gibson (*13, p. 14*) reports that R. A. Vickery found it as a common parasite of eggs of the leaf hopper *Draeculacephala mollipes* Say, and it may attack Diatraea only rarely.

Parasites of the larvae have not been found in Louisiana, but a braconid species has been reared from larvae of *Diatraea zeacolella* Dyar, collected in corn by E. R. Barber at Bennettsville, S. C. A thorough search for larval parasites was afterwards made in South Carolina, Georgia, and Florida by A. G. Davis and U. C. Loftin, but none was found.

Another braconid has been reared by A. W. Morrill, State entomologist of Arizona, from *Diatraea grandiosella* Dyar, which occurs in that State.

A braconid, determined as a new species of Microbracon, was found by J. W. Ingram, of the Bureau of Entomology, to attack both the rice stalk borer (*Chilo plejadellus* Zincken) and the sugar-cane moth borer when boring in rice. This parasite occurs at Crowley, La., but seems to be rare.

Stubbs and Morgan (*29, p. 926*) record a telephorid beetle, *Chauliognathus marginatus* Fabricius, as feeding on the larvae. This is occasionally found in considerable numbers in sugar-cane fields in Louisiana.

During 1916 A. G. Davis found earwigs (Dermaptera) consuming larvae of Diatraea in Florida, and in 1917 George N. Wolcott, in Texas, observed them feeding on eggs of *Diatraea saccharalis* which had previously been parasitized by *Trichogramma minutum*. It is unlikely that the work of earwigs is of any importance in control, and in feeding on parasitized eggs they would, of course, do more harm than good.

The Argentine ant (*Iridomyrmex humilis* Mayr) has been observed feeding occasionally on eggs, larvae, and pupae of the moth borer, but it can not be considered a factor in repression. The ants seem to attack only those eggs which have been parasitized, and while they may sometimes attack larvae they will not ordinarily molest a larva or a pupa unless it has been injured in some manner. The damage occasioned by ants in increasing the number of mealybugs, and as sugar-house and household pests, more than offsets any good which may come from their destruction of insects.

THE EGG PARASITE TRICHOGRAMMA MINUTUM RILEY

On account of its economic importance *Trichogramma minutum* (fig. 17) deserves more extended consideration. It is almost microscopic, and belongs to the large order of Hymenoptera, which includes the bees and wasps. Under the microscope its wings are found to be fringed with delicate hairs and to have lines of these hairs running across their surfaces.

The adults are about one-fiftieth of an inch long, with a wing expanse of a little more than the length of the body. On account of

their minute size they are practically invisible in a sugar-cane field, even though they may be present in great numbers. The best way to find them is to search for a cluster of moth-borer eggs which have turned black (indicating parasitism). During the summer, and especially in the fall, an experienced person can sometimes find these clusters in considerable numbers on the leaves both of corn and of sugar cane. If the eggs are put in a small tube and observed for a few days, many light-yellow Trichogramma adults may be found to have emerged.

In the fields the females of these parasites search for moth-borer eggs very soon after emergence. Finding a cluster, the female inserts her own eggs into the borer eggs, and in the course of eight days or longer, depending on the season, a new generation emerges, the parasites having developed from egg to adult within the moth eggs.

FIG. 17.—*Trichogramma minutum*, an egg parasite of the sugar-cane moth borer, highly magnified. (Riley)

The parasites are scarce at the beginning of the season, and in fact eggs destroyed by them were never found earlier than June 18 in Louisiana. As the season progresses they become more and more abundant, until at last they destroy almost every egg cluster of the moth borer.

If the parasites could be so controlled that they would start their beneficial work earlier in the year, great good would result in limiting the ravages of the moth borer. Low temperatures retard the development of insects, and in an experiment to keep them over the winter parasitized eggs were placed in a refrigerator having a uniform temperature of about 50° F. Some of the parasites emerged even at this temperature, however, and all of them died during the winter.

Under natural conditions they undoubtedly hibernate in the cane trash left on the fields of sugar plantations, and when the trash is burned many of them are probably destroyed. This practice is probably to blame for their scarcity during the following spring and early summer. To avoid the destruction of these beneficial parasites, experiments have been conducted for the last 10 years in conserving the cane trash. The trash may be raked to the headlands or to waste land or it may be plowed under. This subject is thoroughly discussed under the heading "Not burning cane trash," page 56.

Although the egg parasite is assumed to hibernate in the cane trash, all efforts to obtain positive data on this subject have failed. Large, tightly constructed boxes have been filled with the trash and fitted with tubes into which the insects could come to the light, but without result. Sheets of fly paper have been placed through sugar-cane fields in the winter and early spring and afterwards carefully examined. Various small insects were found, but none of this species of parasite.

MOTH-BORER ENEMIES IN FOREIGN COUNTRIES

The minute egg parasite *Trichogramma minutum* occurs almost universally, having been recorded from Cuba, Porto Rico, Trinidad, British Guiana, Barbados, and elsewhere, as noted below.

Box (*5*, *p. 259*) reports the following parasites from British Guiana:

A. Of the eggs.
  Chalcidoidea.
    1. *Trichogramma minutum* Riley.
    2. *Prophanurus alecto* Cwfd. (referred to as Telenomus sp. in early papers).
B. Of the larvae.
  Braconidae.
    3. *Ipobracon grenadensis* Ashm. (probably the *Iphiaulax medianus* Cam., of all other writers on Diatraea in British Guiana).
    4. *Ipobracon puberulus* Szep.
    5. *Ipobracon saccharalis* Turn.
    6, 7, 8, 9. Ipobracon spp. (four species not yet determined).
    10. *Microdus diatraeae* Turn.
    11. *Microdus parvifasciatus* Cam. (referred to as *Cremnops parvifasciatus* Cam. by Moore, Bodkin, and Cleare).
    12. Microdus sp., not yet determined.
  Ichneumonidae.
    13. Mesostenoideus sp.
  Tachinidae.
    14. A dexiine fly determined by the Imperial Bureau of Entomology as "Stomatodexia sp. very near to *S. diadema* Wied." Specimens of this insect were sent to G. N. Wolcott in Porto Rico, who had them named by C. H. T. Townsend as *Leskiopalpus flavipennis* Wied.
C. Of the pupae.
  Chalcididae.
    15. *Heptasmicra curvilineata* Cam.

Box also lists the fungus parasite, *Cordyceps* (*Isaria*) *barberi*, and a number of predators, as follows:

1. An ant, *Ectatomma quadridens* F.
2. Larvae of carabid beetles of the genus Scarites.
3. Larvae of an elaterid beetle, probably Monocrepidius sp.
4. Larvae and adults of the histerid beetle, *Lioderma quadridentatum*.
5. Larvae of a stratiomyiid fly.
6. Attid and other spiders.

From Trinidad, Urich (*30*) records *Trichogramma minutum* and a species of Prophanurus from the eggs, while the larvae are attacked by a tachinid fly, a hymenopteran, Cyanopterus sp., and the green muscardine fungus.

The tachinid *Lixophaga* (*Euzenilliopsis*) *diatraeae* Townsend was found in Cuba by Loftin, as well as a species of Apanteles (probably *diatraeae*). Tachinophyto sp.[10] is recorded by Van Dine (*32*, *p. 199*) from Porto Rico. Rosenfeld and Barber (*27*, *p. 324*, *327*, *331*) record an intestinal worm, the braconid Microdus sp., and a dipteron [11] from Argentina. Van der Goot (*14*, *p. 383*) states that in Java Diatraea is parasitized by *Phanurus beneficiens* Zehntner, *Trichogramma minutum* Riley, *T. nanum* Zehntner, *T. australicum* Girault, in the egg

[10] These flies are thought by C. H. T. Townsend to be probably his *Euzenilliopsis diatraeae*.

[11] According to Townsend, Rosenfeld and Barber's "dipteron," and probably Urich's "tachinid fly" are *Oxysarcodexia peltata* Aldrich.

stage, and by a braconid and a tachinid [12] in the larva stage. He also records two species of ants attacking the pupae and the eggs, and a small carabid feeding on the larva. Emmerez de Charmoy (*11*) notes Telenomus sp., (*Ophion*) *Stauropodoctonus mauritii* Saussure, *Trichogramma australicum* Girault, *Ophion* (*Henicospilus*) *antancarus* [*antakarus*] Saussure, *Apentales* [*Apanteles*] *simplicis* Viereck, and a tachinid fly from Mauritius. Jarvis (*19*, *p. 9*) states that *Diatraea saccharalis* "appears to be under effective natural control in Queensland," while Frederick Muir has told the writers that this is the case in the Philippine Islands also.

A braconid, described as *Apanteles diatraeae* Muesebeck, was found by the senior writer at Mercedes, Cuba, and later by T. C. Barber at Tampico, Victoria, Monterey, and Cuernavaca, Mexico. Mr. Barber found it destroying 50 per cent of the borer larvae, though in Cuba it was rare. He attempted to introduce it at Brownsville, Tex., but his specimens died before he was able to make any releases. It is hoped that another effort can be made to introduce this parasite. Mr. Barber also found a dipterous parasite at Tampico. This is undetermined.

An ichneumonid, *Bassus stigmaterus* Cress., was found by the senior writer at Mercedes, Cuba, but it was rare.

A puparium of a dexiid was found in a borer tunnel in sugar cane at Tepic, Mexico, by H. C. Millender and the senior writer. The fly which emerged was determined as Phorostoma sp. by J. M. Aldrich.

Sarcophaga sternodontus Towns was reared from the pupae of Diatraea in Cuba, by R. H. Van Zwaluwenburg, and was sent by him to Los Mochis, Sinaloa, Mex., together with *Lixophaga* (*Euzenilliopsis*) Diatraeae, in an attempt to introduce these parasites on a large sugar plantation.

Parathesia signifera Towns. was found by Van Zwaluwenburg [13] at Portrero, Vera Cruz, Mexico, and was also sent by him to Los Mochis.

Pentarthron fasciatum Perk., a parasite of the eggs of Diatraea, was collected by A. Koebele in Mexico, as recorded by Perkins (*26*, *p. 19*).

Another egg parasite, *Prophanurus alecto*, Cwfd., occurs in Porto Rico, according to Wolcott (*34*), and Bodkin (*4*, *p. 4*) records it in British Guiana.

ARTIFICIAL CONTROL

DISCUSSION OF THE PROBLEM OF CONTROLLING THE MOTH BORER

There are many points in the life history and habits of the sugar-cane moth borer which make its control very difficult.

The eggs are exposed on the leaves, and a native parasite, *Trichogramma minutum* Riley, destroys vast numbers of them. It does not, however, completely control the borer, even under the most favorable conditions. The practice of not burning the cane trash doubtless preserves numbers of the parasites, and a much lower borer infestation is obtained thereby.

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[12] According to Townsend this is *Diatracophaga striatalis* Townsend.

[13] In a number of typewritten reports on sugar-cane borers and their control to the United States Sugar Cos., Los Mochis, Sinaloa, Mexico.

The newly emerged larvae feed so far within the folded leaves of the plants that it is difficult to reach them with poisons.

Although a larval parasite has been introduced from Cuba, as mentioned elsewhere in this bulletin, it has so far made little or no impress on the infestation, though it doubtless does much good in a limited way every year. The larger larvae and the pupae are concealed within the stalks of the plants, and are thus in a thoroughly protected situation. The moths hide in the daytime and fly only at night. They are not especially attracted to lights and not at all to any baits tested.

The hibernation of the borer presents a vulnerable point of attack. Some borers spend the winter in pieces of sugar cane left about the plantation, and such scraps should be collected and destroyed. Borers are in the stems of some large grasses, at about the surface of the ground, and it is possible to do something in the way of destroying these grasses. In the sugar-cane fields there are some borers in tall stubble, and observations indicate that a heavy infestation in a field is carried over from one year to the next, evidently by borers in the stubble. This can be avoided by cutting the cane properly, without leaving tall stubble. The cane-cutting machine pulled by mules which is sometimes used by Louisiana sugar planters would probably assure a lower and more uniform cutting than hand labor, and the same can be said for other cane harvesters which are not, however, in actual use.

There are so many generations of the borer during the year, and each female deposits so many eggs, that it seems possible for a very few moths emerging early in the spring to cause through their progeny a great deal of damage during the long growing season.

The planting of corn, especially in fields more or less surrounding sugar-cane fields, complicates the problem in Louisiana. The borer passes the winter in planted seed cane and in stubble, as well as in pieces of sugar-cane stalks which may be left about the plantation, and the moths emerge in the early spring and deposit their eggs on the young plants of sugar cane and corn. Great numbers of borers may be produced in the cornstalks, and when these stalks dry out in midsummer the emerging moths fly to the sugar-cane fields, thus increasing the infestation enormously. The situation would doubtless be helped if corn should be replaced by some other crop. The most suitable substitute for corn at this time seems to be soy beans.

The principal source of infestation, however, is the planted seed cane. Where infested cane is planted the borers spend the winter in it, and in the spring they transform into the pupa stage, and later the moths emerge through the loose soil. It happens that the system of cultivation in Louisiana encourages this emergence of the borer. The soil is partly removed from the stalks in the process of "off-barring," and much of what is left is loosened and pulverized in cultivating. The borer moths can emerge more easily through a thin layer of loose soil than through a thick layer of packed soil.

If the borers can be killed in the stalks that are to be planted, however, it makes the problem much easier of solution. Two treatments are available for the elimination of borers from seed cane before planting, namely, the hot-water method and the treatment with water of

ordinary temperatures. These methods are explained in detail in the following pages, in which a number of practices and methods of control are discussed.

CUTTING OUT "DEAD HEARTS"

The dead plants, or "dead hearts," which follow the work of the moth borer in the spring, contain for a few weeks the larvae which have killed them. A familiar recommendation has been to cut out these dead plants and burn them, care being taken to cut to or even below the surface of the ground so as to secure the larvae.

The writers had an opportunity of observing this work in progress on a large scale at the State penitentiary farm at Angola, La., in the spring of 1917. The cutting of the "dead hearts" was being done very efficiently by convicts. They collected the dead plants in bags and burned them on the headlands. It was the opinion among the foremen that the "dead hearts" should be cut out of each field three times during the early growing season. One man was said to cover 4 acres per day.

The writers made a point of revisiting the penitentiary farm in the fall to ascertain the results of the work. It was found that the average infestation of the whole plantation was 31.5 per cent, which for 1917 was not extraordinarily low. Around Port Allen, La., for instance, the average infestation was 30.7 per cent, and the "dead hearts" had not been cut out at that place. Individual fields at Angola ran from 6 to 85 per cent, and at Port Allen from 9 to 94 per cent.

It is possible that the different fields at Angola did not all receive exactly the same treatment as to cutting out the "dead hearts," especially as the plantation is divided into a number of farms or sections, each of which has its separate manager. As far as the authors could ascertain, however, the treatment had been uniform over the whole plantation.

It was the opinion of several of the farm managers that cutting out the "dead hearts" would not be practicable on a plantation where unpaid convict labor is not available.

Moore (*24*) records the collection of 15,285,960 larvae and pupae of the moth borer on 17 estates in Demerara, British Guiana, in 1912, and 13,632,655 in 1911. He then remarks:

> The effect upon the pest of all this terrific slaughter has not as yet been very marked, but will increase more and more rapidly if the destruction be kept on persistently, systematically, and relentlessly. The insect propagates at such a very rapid pace, in spite of the counteractivity of a variety of natural enemies, and in spite of whatever may be the weather conditions, when its seasons come round, that to overtake it and bring it under proper control must needs be a rather long undertaking.

CUTTING CANE PROPERLY

It has been observed that borers can spend the winter in tall sugarcane stubble and that a heavy infestation may be carried over in this way from one year to the next. The cane should be cut low, so as to eliminate tall stubble which can harbor the borer. It is believed that more uniform results can be secured with the mule-drawn cutting implement than by hand labor, although it is necessary for

laborers to precede the machine in order to top the stalks and free them of the lateral leaves.

DESTRUCTION OF SCRAPS OF CANE LEFT AFTER GRINDING

One of the chief places of hibernation of the moth borer is in scraps of cane left about the plantation. The wise manager will therefore collect such scraps as soon as possible after the grinding season and destroy them. On a plantation on which many scraps had been left about the mill and the derricks from one season to the next the infestation was practically 100 per cent over the whole plantation.

After the scraps are collected they may be disposed of by a very thorough burning with oil or some dry material. Throwing the scraps into a lake or other body of water is not to be recommended, as some of the moths may emerge from the floating stalks or from those which are washed ashore. Passing the scraps between the rollers of the mill has been recommended, but this would hardly be practicable on the ordinary plantation.

As to the tops left on the fields in the process of turning under the "trash," these are not usually badly infested, and they decay so thoroughly during the winter that they become unsuitable as food for the borer.

THE KANNAN METHOD OF ATTRACTING ADULTS TO HEAPS OF TRASH

In 1923 Kannan (*22*, *p. 13*) outlined a method of catching the adult moths. Handfuls of cane trash were placed through the fields early in the season. The moths of the species of Diatraea with which he was working in India sought refuge in these piles of trash, and it was an easy matter to examine the trash and crush the moths found. According to his observations, an infestation was reduced to between 2 and 5 per cent, while the previous year 50 per cent of the canes had been infested.

This method was tried by the writers in Louisiana during May, 1923, but without success. No moths were found in handfuls of trash scattered through the fields as Kannan advised. The unsatisfactory results doubtless were due to the fact that the American species of borer is different from the one in India and undoubtedly has somewhat different habits.

FALL PLANTING

Windrowing seed cane for spring planting is a practice which affords the borer an ideal place to spend the winter. The insects can crawl from one stalk of cane to another in the windrow, killing many eyes which otherwise would germinate. The covering of earth and leaves protects the borer as well as the cane from the severities of winter.

Planting the cane in the fall instead of in the spring does away with the necessity for a windrow altogether, and is to be preferred. This is one of the recommendations of Stubbs and Morgan (*29*, *p. 914*, *923*). Fall planting is practiced as far as labor and time will permit on most Louisiana plantations.

DEEP PLANTING OF SEED CANE

To determine whether moths would emerge from planted seed cane, infested stalks were buried under various depths of soil in boxes which had been raised from the ground and isolated from ants. The soil used the first year was ordinary black soil found at the sugar experiment station, Audubon Park, New Orleans, technically called "Yazoo clay." The cane was buried at the following depths: One-half inch, 1 inch, 2, 3, 4, 5, and 6 inches. The soil was packed on the cane, and the depths of earth were accurately determined. By covering the boxes with wire screen the capture of any emerging insects was assured. One female moth emerged from the cane buried under one-half inch of soil, while no moths emerged from cane buried at other depths.

This experiment was repeated the following year, using river sand as well as black soil (Yazoo clay) as before. The cane was buried at depths of one-half inch, 1 inch, 2, and 3 inches. Three moths emerged from cane buried under one-half inch of river sand, while no moths emerged from cane buried at other depths. No moths emerged from any of the cane buried in the black soil.

The experiment indicates that the moths can emerge from cane under one-half inch of either clay soil or sand, more moths emerging from sand. Planters would, therefore, do well to keep the planted cane well covered with soil, especially in sandy land.

It would seem that planters could utilize this information by planting the cane fairly deep, but little would be gained by this practice because at the time the moths are emerging in the spring the earth on the planted cane is partly removed and loosened in the process of "off-barring" and cultivation. Unfortunately, this partial removal and loosening of the soil, while benefiting the cane, also allows the emerging borer moths to reach the light and air.

DESTROYING OLD CORNSTALKS

Though hibernating larvae have been found in cornstalks in Texas, especially in the lower Rio Grande Valley, they have not been found in this food plant on Louisiana sugar plantations. The corn on sugar plantations in Louisiana is planted fairly early and by midsummer the stalks begin to die and dry out, no longer furnishing an acceptable food for the borer. The borers already in the stalks pupate, and the moths emerge, leave the cornfields, and fly to the adjacent cane fields to lay their eggs.

The stalks of late corn would probably provide a hibernating place for the sugar-cane moth borer larvae, but as only early corn is grown at present, it seems that there is little danger from old cornstalks and that special efforts need not be made for their destruction.

CURTAILING CORN PLANTING

The moth borer multiplies more rapidly in corn than in sugar cane, and many more borers can be supported in a stalk of corn than in a stalk of sugar cane. Cornstalks are often found riddled with borers, with as many as 40 or more in a single stalk, while a stalk of infested sugar cane usually contains not over three borers.

The Louisiana sugar planters have about a third of their land in corn, and the corn and the sugar-cane fields happen to be planted in a sort of checkerboard fashion. A field of sugar cane, for instance, may be entirely surrounded by cornfields, though this occurs without any intent on the part of the planter.

The growing of corn on sugar plantations, especially the distribution of cornfields among the sugar-cane fields, tends enormously to increase the damage from the sugar-cane moth borer. To prevent this, the writers have recommended as an experiment the curtailment or even the nongrowing of corn on sugar plantations.

At Wallace, La., there are three plantations in a group, more or less isolated from other plantings of corn or cane. One has grown practically no corn for a number of years. Another planted no corn in 1925. The third, adjoining this one, planted corn as usual.

The results were:

Plantation growing corn as usual, sugar-cane infestation 100 per cent, or every stalk bored.

Adjoining plantation, not growing corn in 1925, sugar-cane infestation 89 per cent.

Plantation adjoining, growing practically no corn for years, sugar-cane infestation 84 per cent.

Far better results might have been obtained if none of the three plantations had grown corn. However, even the partial elimination of corn evidently reduced the infestation on the lands where it was practiced.

Many planters think that on Louisiana sugar plantations corn is produced at a loss, and on the whole this view seems to be correct. In planting corn a real rotation of crops is not secured, as corn and sugar cane are members of the grass family and take the same elements from the soil.

It seems that the best crop to take the place of corn is soy beans. On some rice plantations in Louisiana the beans are harvested and the dead plants are plowed under, adding vegetable matter and fertilizing elements to the soil.

PLANTING CORN IN SOLID BLOCKS

Some attempt has been made by sugar planters to plant corn in large blocks, isolated as far as possible from the fields of sugar cane by such crops as cotton and soy beans. In practice this is a difficult matter, as the cooperation of tenants and neighbors can not always be readily obtained.

The results would probably be similar to those of the experiment in the partial elimination of corn reported above—that is, a slightly lower infestation would be obtained.

POISON ON YOUNG PLANTS

By covering the young plants with an arsenical in powdered form, which was suggested by Loftin, it was hoped to present a poisoned-leaf surface to the first young borers of the year. Before gnawing into the plants the newly emerged larvae feed among the leaf whorls for a limited time. It was thought that if they could then be poisoned much damage later on could be prevented.

A small preliminary experiment gave what seemed to be promising results, and a large plantation experiment was planned. Fields on a typical plantation were poisoned one, two, and three times, powdered lead arsenate being used, and the applications being made at many different dates in the spring. After nearly every application, however, there was a heavy rain, and in the following fall no benefit could be observed. About 2 pounds of poison per acre were applied, a special horse machine being used.

The experience gained proved that the machine, which was designed for cotton, was not well adapted to sugar-cane fields, so in the following year the framework was strengthened and a gasoline engine added. This gave a much more uniform distribution of the poison, and an application of 2 pounds per acre covered the plants rather thoroughly. One man and a two-horse team with this machine could cover 35 acres per day, at a total cost for labor and material of 64 cents per acre. The apparatus used in the test is illustrated in Figure 18.

A 125-acre field at Belle Alliance plantation near Donaldsonville, La., which was naturally divided into approximately 5-acre plats by drainage ditches, was selected for the experiment. One plat was poisoned once a week during the nine weeks from April 18 to June 14, while other plats received from one to four applications of 2 pounds per acre at weekly and fortnightly intervals beginning at different dates during the nine weeks' period. The season was rather dry, and rain did not interfere with the work any more than might be expected under Louisiana conditions.

Borer eggs and "dead hearts" were observed throughout the spring and summer in the various plats, and in October, when status examinations were made, considerable variation was found in the different plats, but no relationship between the poisoning and borer infestation could be established, the treatment evidently having no effect whatever.

Applying poisonous dusts (notably sodium fluosilicate, called also sodium silico-fluoride) to sugar-cane fields by airplane was tried during 1925 and 1926 by W. E. Hinds and Herbert Spencer (*15*, *16*), entomologists of the Louisiana experiment stations. The announced results of this dusting were such that in 1927 funds were allotted for the dusting three times by airplane of 5,000 acres of the new P. O. J. varieties of sugar cane with this chemical in the hope that the treatment would ensure sound seed cane for those growers who had suffered from the great river flood of 1927.

The dusted fields were scattered along a line in Louisiana from New Roads to Lockport and then to Lafayette. From one to three airplane applications of about 16 pounds per acre were made in various fields, starting August 1, and dusting a given field at about monthly intervals. These dustings were followed by very careful examinations by trained men.

It was found that there was a maximum "kill" of 28.1 per cent among larvae and pupae, but that there was a natural mortality of 8.5 per cent, giving a net kill of less than 20 per cent. This effect was largely among the small borers outside of the stalks, and included only a small number of large larvae and very few pupae. Even the low figure of 20 per cent does not take into account the eggs

and moths which might have been in the fields and which were unaffected by the poison.

In spite of the fact that about one-fifth of the larvae and pupae were killed at monthly intervals, it was found at the time of cutting

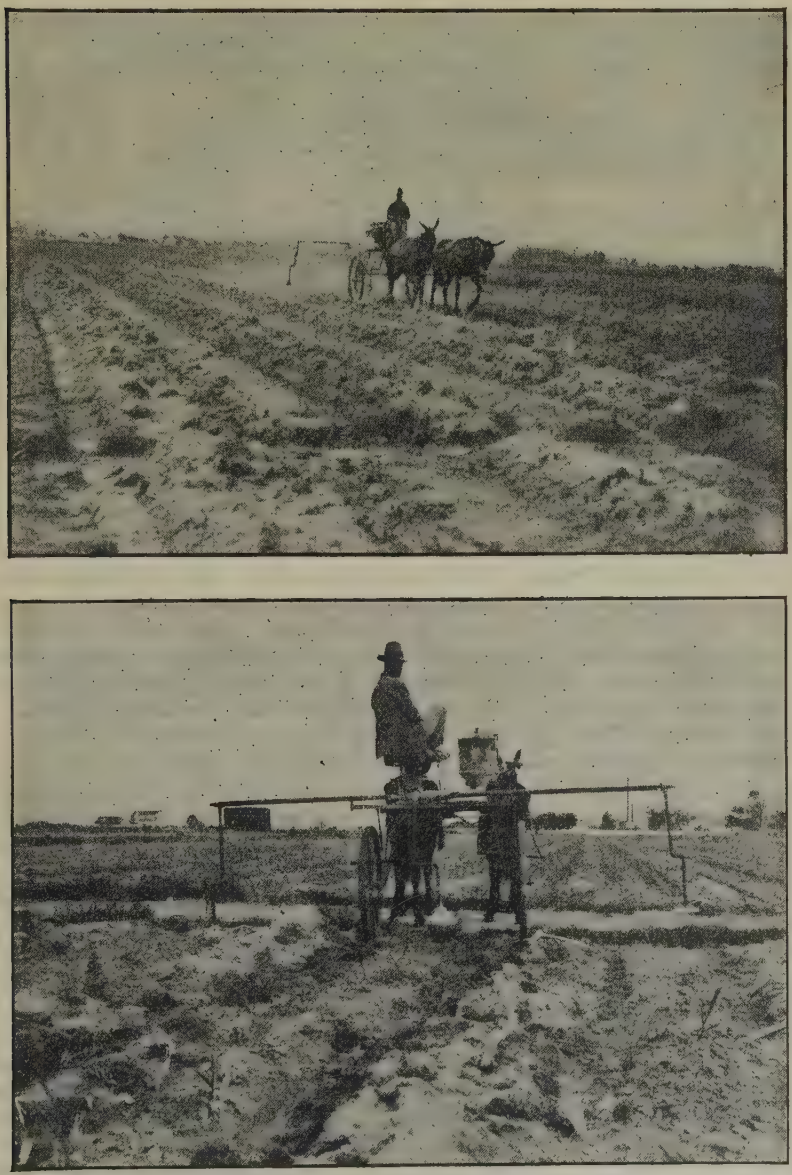

FIG. 18.—Dusting young cane plants with powdered lead arsenate. Poison has not been found successful in controlling the moth borer

that the infestation on the whole had not been reduced. Examinations were made on fields in 13 localities before and after the treatment, and with one exception it was found that in both the check and the

dusted fields the infestation had increased uniformly, often up to nearly 100 per cent of the stalks. The joint infestation was also uniform.

The details for the one exception are as follows: Before dusting the stalk infestation in each field was 30 per cent, with one joint bored per infested stalk; after three dustings in the treated field 77 per cent of the stalks were bored, with four joints bored per infested stalk, while in the check field 89 per cent of the stalks were bored, with five joints bored per infested stalk. The rather slight reduction does not constitute control, and as it is the exception in 13 tests it might have been due to some factor other than the dusting.

It is believed that the reproductive powers of the species is so great that the destruction of 20 per cent of the larvae and pupae each month for three consecutive months has very little effect on the damage done to the cane crop.

The cost of the three applications was approximately $8 per acre. In addition there was some expense due to the carting and storing of the poison, and in some cases it was received in a caked condition, which necessitated pulverizing.

The dusting was not only of no benefit in the control of the moth borer, but it was injurious to the cane, causing a burning of the leaves and a consequent stunting of the plant.

REACTION OF ADULTS TO HONEY AND OTHER BAITS

In the control of certain pests of vineyards in Europe, baits composed of fermenting molasses and other substances have been reported as successful in attracting the adults. In fact the use of these baits appears to be a well-established practice in some communities. It is also well known that collectors often make use of a mixture of stale beer or rum and brown sugar for attracting certain night-flying moths. It was thought worth while, therefore, to test the attraction of various chemicals and mixtures for borer moths.

Five modified flytraps were hung in cane and cornfields known to be infested. All the traps were baited with the same substance at a time, and were left in the fields for at least 24 hours. The following mixtures and chemical compounds were experimented with: Honey; honey, water, and alcohol; 1 part honey dissolved in 3 parts alcohol; stale beer, low-grade sugar, and alcohol; stale beer and sugar; oil of anise; imitation strawberry sirup; orange-flower sirup; cedar oil; solution of citric acid; pyridin; xylene; vanilla extract; oil of citronella; oil of wintergreen; oil of cinnamon; formaldehyde solution; pennyroyal; fluid extract of valerian.

No borer moths and very few other insects were captured.

Moths were later placed in cages with a piece of cotton saturated with a chemical, and observations were made on their movements. The following chemicals were used: Nitrobenzene, dichlorobenzene (ortho- and para-mixture, technical), o-dichlorobenzene, bromobenzene, p-dibromobenzene, chlorobenzene, alphachloronaphthalene, aniline, oil of cloves, a commercial grade of chloronaphthalene, paraformaldehyde, oil of anise, vanillin, and oil of almonds.

There was no attraction, except, in one experiment, to bromobenzene. Three moths were placed in a cage with this chemical, and they were all found resting on the saturated cotton. One was alive, and the others were dead. The live moth was removed from the

cotton, but half an hour later it was found on the cotton again. A cage was then started with six moths, but they were all apparently indifferent to the chemical. In a heavily infested greenhouse no moths were attracted to it.

REACTION OF ADULTS TO LIGHTS

Attracting the adults to lights has been proposed occasionally as a means of controlling the moth borer. It seems evident, however, that lights can exercise little attraction for them. The moths avoid the sunlight and remain concealed during the day in dark places, such as between the leaves and the stalk of a sugar-cane plant. If disturbed they fly for a short distance, seeking another place of concealment. As dusk approaches, however, they become very active, but daylight finds them motionless again.

Experiments have been conducted with insect light traps, which are so constructed that insects which fly to the light will be killed by a poisonous gas and fall into a jar, from which they may be removed at the convenience of the collector. A commercial moth trap was used. Some of the traps were fitted with glasses of various colors, so that they would throw colored lights, and they were equipped with electric lights of high candlepower in addition to the kerosene lamps with which they were furnished by the manufacturers.

A light trap was placed about 20 feet from a plat of young corn which was heavily infested by the moth borer. A clear light of about 60 candlepower was used. The trap was run on 16 nights between September 16 and October 13. The catch of borer moths was as follows:

Sept. 16	4 males, 1 female.
Sept. 17	13 males.
Sept. 18	18 to 20 males, 4 females.
Oct. 6	1 male.
Oct. 9	4 males
Oct. 10	1 male.
Total males	41 to 43.
Total females	5

Borer moths were caught on only about one-third of the nights during which the trap was operated, and practically no females were secured. The few females caught apparently had deposited their eggs already.

A much more elaborate series of experiments was conducted in the following year. From May 12 to June 18 five traps were operated with kerosene-oil lamps, the traps being fitted to throw lights of the following colors: Green, yellow, clear (uncolored), red, blue. As no borer moths were caught, the traps were provided with carbon-filament incandescent electric lights of about 80 candlepower. A mottled brown-and-yellow glass was substituted for the yellow, which had been broken. The traps were operated during July, August, and September, with the following catches resulting:

Clear glass	58 males, 2 females.
Mottled	26 males.
Green	18 males.
Blue	15 males.
Red	0
Total males	117
Total females	2

Neither of the females which were attracted to the clear light contained eggs.

The lights were arranged so that they were about 6 feet from a field of sugar cane. Observations were made to determine whether the number of canes infested by the moth borer had been lowered by the proximity of the lights, but this was not found to be the case, the infestation being as high as usual.

A year later more experiments were conducted, larger traps made on the same principle as those previously employed were used fitted with glasses of standardized colors prepared for railroad semaphore lights. The colors used were purple, blue, red, green, brown, and clear. The lights were operated on 54 nights from May 9 to September 4, the captures being as follows:

Purple	5 males, 4 females.
Blue	5 males.
Red	0
Green	6 males.
Brown	1 male.
Clear	44 males, 2 females.
Total males	61
Total females	6

At the suggestion of E. R. Barber experiments were conducted on three nights in September with a 750-watt light taken into a cane field and operated by means of a long extension wire. It was observed that the moths would rise and then settle on the plants again, not continuing to fly around the light. Two males and five females were caught. There was some doubt as to whether two of the females had deposited their eggs, but the remaining three were certainly gravid.

The operation of lights has also been observed on a certain Louisiana plantation on a much larger scale, gasoline torches being pulled about over the plantation. One was equipped with a gasoline engine and other apparatus which caused a powerful suction of air back of the light, the insects being sucked into an inner chamber. The other arrangement was a train drawn on the plantation railway, consisting of a locomotive pulling a tank car filled with gasoline and a flat car bearing two huge gasoline burners, which produced flames 5 or 6 feet high. The lower parts of the flames were about 10 feet above the ground. The plantation management made a practice of operating the train on favorable nights during the summer, and the expense in 1916 was said to be about $7 per night. On the night of August 25 the senior author saw both machines in operation and examined 22 borer moths, of which 5 were males and 17 were gravid females. The moths would fly near the flame, their wings would be singed, and they would drop to the ground; or, in the case of the suction or vacuum outfit, they would be drawn with great force into the inner chamber. The fact that these machines were drawn through the midst of the cane fields may account for the variance of the results with those obtained with the light traps. As the lights were moved from one spot to another, group after group of insects was observed to rise. As soon as the insects had either settled or been captured or burned at one point the machines were moved a few yards farther on and a new group would start up.

It was expected that this plantation would have a low infestation in the fall. Fields were examined near which the lights had been operated and compared with other fields which had not been reached by the lights. The average infestation of canes was 96.7 per cent for the treated fields, while it was 97.3 per cent for the untreated fields, a difference of less than 1 per cent. The average infestation of all the fields examined as compared with the average infestation of other plantations in that part of the State not using the lights was higher rather than lower.

Even with the high percentage of females taken at the plantation lights it is apparent that with regard to percentage of canes infested the lights have no effect on the moth borer.

FIG. 19.—Control of the sugar-cane moth borer. Sugar-cane field after the cane has been cut and removed, showing heavy covering of leaves or trash

BURNING CANE TRASH

In the process of harvesting sugar cane the tops of the plants and the lateral leaves are cut off and left in the fields, forming a quantity of fibrous vegetable matter almost universally called "the trash." (Fig. 19.) A common recommendation has been to burn this débris as soon as it is dry enough, which is within a few weeks after the cane has been cut. Apparently burning would tend to decrease the subsequent infestation by the moth borer, but this has not been found to be the case. Examinations of the trash indicate that comparatively few borers are usually to be found in it, most of them being in the stalks of the cane, which are carted from the field and ground in the mill, thus disposing of the greater number. On the other hand, the trash is a favorable hibernating place for numbers of dipterous and hymenopterous insects, many probably of beneficial species. The eggs of the moth borer are deposited on the leaves of the cane plants, and these are attacked by the egg parasite *Trichogramma*

minutum. It is probable that these minute beneficial insects are destroyed in great numbers when the trash is burned.

Louisiana sugar-cane planters have been burning over their cane fields for many years (fig. 20), and it has not been found that any reduction in the number of canes infested by the moth borer results. It is the opinion of the authors, after having made many field observations, that trash burning can not be expected to diminish the number of canes infested, whereas it may increase the infestation by destroying beneficial insects. An objection to trash burning, admitted even by its advocates, is that ordinarily it is not done thoroughly. The dry leaves which burn readily are consumed, but there are left in the fields short pieces of cane, which sometimes contain living borers, even though they have been considerably heated and charred by the

FIG. 20.—Burning cane trash

fire. It is evident that trash burning, while unquestionably destroying many beneficial insects, frequently fails to destroy the few borers left in the field, because of their protected situation in pieces of cane which do not burn readily.

When it is remembered that there are four or five generations of borers per year, that about half of the adults are females, and that each female lays an average of 200 eggs, it will be realized that a very few borers passing the winter successfully are sufficient to infest a whole plantation, especially if their parasites have been destroyed.

NOT BURNING CANE TRASH

To protect the egg parasite the senior author some years ago began experiments in disposing of cane trash by plowing it under and by raking it to the headland.

On one plat at the sugar experiment station, Audubon Park, New Orleans, the cane trash was burned in the fall of 1912 as usual, while on another plat of about the same size the trash was raked to the

headlands in the spring before cultivation. Through the growing season of 1913 careful examinations were made to ascertain the infestation in the two plats, and even in the spring and early summer the results were promising. For a long time no borers were found in the unburned plat, whereas borers and "dead hearts" were found in the burned-over plat, but when the cane was cut in October the difference was most striking. In the burned-over plat 67.5 per cent of the canes were infested by the borer, while in the unburned plat only 15.5 per cent were infested.

On a plantation in the lower Rio Grande Valley of Texas no cane trash was burned in the fall and winter of 1912–13, while on neighboring plantations under the same management the trash was burned in the fall as usual. When examinations were made in the fall of 1913 the difference in infestation was easily discernible. The average infestation of the unburned fields was 30.6 per cent, while the average infestation of the burned-over fields was 76 per cent. In 1912 the average infestation of these plantations was 50.5 per cent and in a field a few miles away it was 86 per cent.

In 1914 various experiments were conducted at Audubon Park. Trash was burned in the fall, burned in the spring, raked to the headland in the spring, and plowed under in the spring. The results of these experiments are recorded in Table 8.

TABLE 8.—*Nonburning experiments, Audubon Park, New Orleans, La., 1914*

Kind of treatment	Number of plants infested by borer, May 29 to June 2, 1914	Number of plants killed by borer, Oct. 28 to Nov. 2, 1914	Percentage of canes infested by borer, Nov. 2 to 5, 1914
Trash left on field in winter and plowed under in spring	3	3	45.73
Trash left on field in winter and raked to headland in spring	6	12	63.31
Trash burned in fall as usual in Louisiana	5	38	83.79
Trash left on field in winter and burned as soon as possible in spring	20	6	69.44

NOTE.—The plants infested May 29 to June 2 ("dead hearts") were cut out and destroyed about June 10, so that the plants killed by Oct. 28 to Nov. 2 were different plants which had been infested later in the season. The dates refer to the times examinations were made.

In each of these plats there were about 20 rows of cane. Three plats were in one field, not separated in any way, while the plat on which the trash was burned in the spring was separated from the plat on which it was burned in the fall by a plantation roadway about 20 feet wide. Needless to state, these conditions were not of the best for the experiments. It would have been better if each plat had been comparatively isolated from other plats of cane, so that there would have been no danger of the insects going from one plat to another.

It will be noted that the infestation at the end of May was almost negligible in all plats, but even then the least injury was in the plat where trash was plowed under in the spring. By October 28 the most conspicuous injury ("dead hearts" and large plants killed) was small, but the difference between the plats subjected to different treatments is notable. Again, the smallest number of killed plants (3) was found in the plat where trash was left on the field in the winter and plowed under in the spring. Fall burning gave as many

as 38 plants killed. In the plats where the trash was raked to the headland in the spring, and where it was burned in the spring, there were 12 and 6 dead plants, respectively—several times more than where the trash was plowed under in the spring. A few days later, when the cane was cut, a careful examination was made of over 600 canes in each plat. Where the trash was burned in the fall the infestation was nearly 84 per cent, but where the trash was plowed under in the spring it was only about 46 per cent. The experiments in raking the trash to the headland and in burning it in the spring gave about 63 and 69 per cent, respectively. From these experiments spring burning seems to be better than fall burning and plowing the trash under in the spring better than either. (Fig. 21.) Raking the trash to the headland for some unknown reason did not give as good results in 1914 as it did in 1913.

FIG. 21.—Cane field, showing leaves or trash plowed in. The stubble was plowed up in the same operation

Extensive experiments on plantations in Louisiana were carried on in 1915, 1916, and 1917. During 1915 and 1916 the results were negative, the infestation being about the same on fields where trash was not burned as where it was burned. The fields not burned were usually in the midst of other fields which had been burned over. Yet in 1916, when the trash was not burned except on one field at Audubon Park, the infestation was much lower there than anywhere else in the State, with the exception of two places which had been flooded. The average infestation in Louisiana for 1916 was 75.5 per cent, while the infestation at Audubon Park was only 38.3 per cent.

The reason for the difference between the results on plantations and those at Audubon Park was not understood until it was suggested in 1917 by W. G. Taggart that the relative isolation of the fields at Audubon Park had prevented the reinfestation of the unburned fields by moths flying from other plantations. This explanation seems to be correct, and the latest results tend to confirm it. The average infestation in Louisiana in 1917 was 45.8 per cent, as

compared with 20.3 per cent at Audubon Park, where the trash was not burned on any of the fields but one. Comparing this burned-over field with an average of the other stubble fields, there was an infestation of 38 per cent for the burned-over field, while the average infestation of eight unburned stubble fields was 20.2 per cent, with 36 per cent as the highest infestation on an unburned field.

Following this the trash was left unburned at the sugar experiment station, Audubon Park, New Orleans, La., for a number of years, while the planters as a whole burned their trash. A comparison of the loss (not infestation) year by year at Audubon Park and over the sugar parishes in general, as shown in Table 9, is of interest.

TABLE 9.—*Percentage of loss due to moth borer*

	1915	1916	1917	1918	1919	1921
Audubon Park	12	13	7	19	6	18
State average	24	30	17½	21	9	25

The average of all the years gives Audubon Park a loss of 12.5 per cent as against a State loss of 21 per cent. Before trash conservation was adopted at Audubon Park, however, the loss there was similar to the loss over the State.

More recently, figures were obtained on Columbia plantation, near Franklin, La. In 1925, when no trash was burned, Columbia had a loss of 15.8 per cent, while the State average was 30 per cent. That is, Columbia suffered only about half as much damage as the average plantation.

The plantation results in 1917 were in accord with the theory that isolation of fields influences the results of nonburning, using the term "isolation" to mean not only a situation detached from other cane plantings, but one separated from plantations where the trash is burned. In a locality in the midst of the sugar parishes a typical plantation (designated *A* on the diagram, fig. 22), fronting on the Mississippi River and running back to swamp land, was not burned over, the trash being plowed under in the fall. This plantation was bordered on the north by a burned-over plantation *B*, and on the south by a much smaller plantation, *BB*, a long and narrow strip of land which had also been burned over. But bordering these plantations was one on the north, *C*, in which only part of the trash had been burned, the rest having been plowed under, and one on the south, *CC*, treated in the same way. Plantation *A*, where the trash had not been burned, while bordered on each side by burned-over areas, was yet the center of a district where much of the trash had been saved. The infestation at *A* was 22.5 per cent, and at *C* and *CC* it was 56.9 per cent and 53.6 per cent, respectively. At *B*—burned over, but between *A* and *C* and undoubtedly influenced by the trash saved at those places—it was 49.5 per cent. Plantation *BB* was overlooked, and the infestation is not known, but at two places in the vicinity, *D* and *DD*, both burned over, the infestation was 77 per cent and 75 per cent, respectively. The map will convey a more accurate idea of the situation than any further explanation, but the following

points should be noted: At the two burned-over plantations, *D* and *DD*, farthest away from unburned fields, the infestation was high, about 75 per cent. At the two partly burned plantations, *C* and *CC*, is was medium, about 55 per cent. At the burned-over plantation *B*, bordered on each side by unburned or partly burned fields, it was also medium, 49.5 per cent. At plantation *A*, not burned and the center of a nonburning region, the infestation was the lowest of all, only 22.5 per cent.

It is evident that a plantation must be considered as a unit in determining the infestation. The former custom was to consider a field as a unit, to which there is the objection that the moths of the borer can fly readily and doubtless reinfest areas in which the parasites have gained the ascendency. Although a comparison of fields at Audubon Park is not unsatisfactory, it is true that the fields there are small, and they are not surrounded by vast stretches of cane and cornfields which are typical of the sugar parishes.

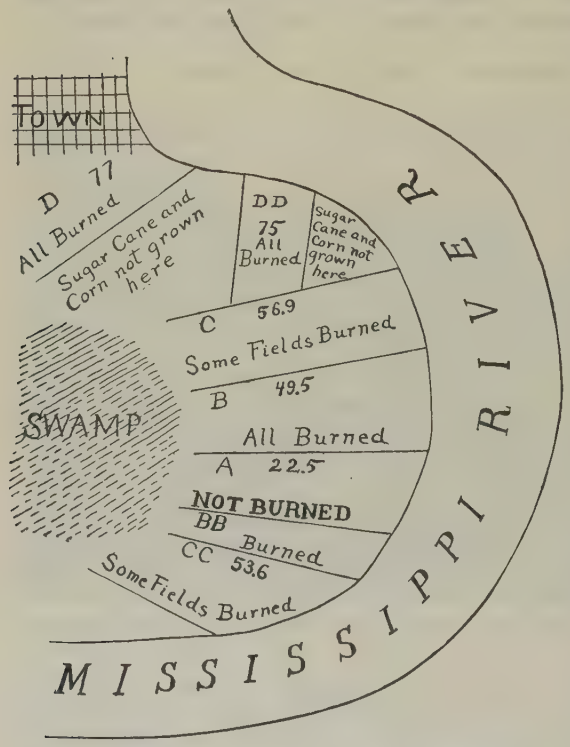

FIG. 22.—Diagram of plantations showing percentages of infestation by the sugar-cane moth borer in relation to nonburning of cane trash

The results in 1917 indicated that nonburning would be effective on isolated areas of any size and on nonisolated areas so large that the bordering burned-over fields would have little effect on the general infestation. An illustration of nonburning on a single narrow plantation surrounded by burned-over areas was obtained in 1917. In this case nonburning was apparently of no benefit, the infestation being slightly, if any, lower than at a neighboring place. Yet the benefit to the land of plowing under the trash is considerable, and as it is only by degrees that the new practice will become established no planter should hesitate to practice nonburning because his neighbor refuses to do so.

A planter who has plowed under his trash told the writers that it maintains the tilth of the soil from year to year, and the difference between the condition of the soil where trash has been plowed under

and where it has been burned is immediately perceptible. Where the trash is plowed under the soil is left open and porous and is enriched by the nitrogen and other fertilizing elements of the decaying vegetation. (Fig. 23.)

The work of plowing out the trash in the spring is regarded by some planters as so great that they refuse to leave it on the fields unburned. At the sugar experiment station the process of caring for the trash, to quote from an unpublished statement by W. G. Taggart, assistant director, is as follows:

In plowing under cane tops, especially on land where stubble is to be held for the following year, the work must be done in such a manner as not to injure the ratoons, and at the same time to hasten decomposition of the trash. The last object can be best attained by covering the tops with two furrows by

FIG. 23.—Partially covering cane trash with two furrows to a row to hasten decomposition during winter

the turning plow, before the green material has dried out. If the labor and teams are not available at the time, it is next best to do the plowing when the tops are as wet as can be handled without danger of damaging the mechanical condition of the soil. We find that two furrows, run as far away as possible from the old ratoon, and at the same time just deep enough to cover the trash lightly, are satisfactory. This practice practically allows all trash to be held continuously in a moist condition with free access to air, thereby hastening oxidation and decomposition. The partially decomposed vegetable matter is thoroughly and deeply buried at the usual time in early spring when cane is off-barred. Under average conditions of tonnage and winter rainfall we have found that cane trash treated according to this method will decompose sufficiently to allow cultivation of the middles without undue cost or inconvenience. However, when a heavy crop of tops has been turned under considerable difficulty may be experienced in throwing out the middles, unless the job is undertaken in two operations. First, whatever implement is assigned to this task should be run in such manner as to skim over the main layer of trash; the second furrow can then go deep enough to undermine any trash which has not been decomposed, and divide it along the side of the two rows where the following cultivation, preferably with a disc cultivator, will completely mix all this organic matter, with its humus and nitrogen, into the seed bed.

Practically the same method was used on the large plantations where the trash was left in 1916 and 1917. The labor of the first cultivation was said by one plantation manager to be about doubled and to cost about $1 more per acre than cultivation after burning. A plantation owner estimates an additional cost of $1.50 per acre. This is a very small amount to spend for the possible control of the moth borer, and is slight as compared with a maximum loss of nearly $50 per acre. Stubbs (*28, p. 87*) calculates that for every ton of cane there are left in the trash 1.9 pounds of nitrogen, equal to the nitrogen in 27 pounds of cottonseed meal, while Mr. Taggart has told the writers that there are 556 pounds of organic matter in the trash from 1 ton of cane. All this nitrogen and organic matter is lost in the burning of the trash, but preserved when it is buried. Considering the chemical and mechanical benefit to the soil, the possible insect control really costs nothing at all.

On the subject of nonburning, Earle (*9*), formerly director of the Cuba Experiment Station, writes as follows in the *Cuba Magazine:*

> To the general burning of the trash in the fields after cutting there are, however, many valid objections under conditions existing in Cuba and Porto Rico. On many soils this trash is badly needed to keep up the supply of humus, but more particularly it is needed as a mulch to protect the soil from excessive drying out during our long periods of winter drought. Aside from this, the universal burning of the trash would involve an amount of summer cultivation to keep down weeds and grass that would be entirely beyond the present equipment and labor supply of most of our plantations. In other words, it is impracticable. The best we can hope in the direction of ratoon cultivation is to move the trash and cultivate alternate middles. Nor is there any reason to suppose that burning the trash would give us any real protection from the borer. Cultural conditions in Louisiana are so different from ours that the burning of the trash is practically a necessity and it is universally practiced.[14] We do not, however, find that this gives them any immunity from the borer. On the contrary, they suffer fully as much as we do. This very likely may be due to the fact that burning destroys borer parasites as well as borers.

LEAVING PILES OF TRASH FOR THE HIBERNATION OF THE EGG PARASITE

A few plantation men in Louisiana have advocated the leaving of some armfuls of cane trash for the hibernation of the egg parasite and burning all the rest of the trash in the field. Sticks or branches were laid across a drainage ditch, and on these perhaps half a dozen armfuls of trash were thrown. It was said that one such trash pile was sufficient for every 2 acres of land; all the rest of the trash over the 2 acres, amounting to many tons, might then be burned.

It seems to the writers that this recommendation is founded on the assumption that the parasite knows as well as the planter that the trash in general is to be burned, while the small quantity over the ditch is to be left. The parasite is supposed to leave the main body of the trash, in which it may have found satisfactory hibernating quarters, and take refuge in a small pile which has been provided for it. Of course such an assumption is absurd. The fire over the cane field must destroy practically all the parasites and leave only a few which may possibly be in the pile.

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[14] Earle is writing of conditions in Porto Rico and Cuba, with which he is more familiar and takes it for granted that burning the trash in Louisiana, at that time universally recommended, is a necessity.

The whole suggestion is an evasion of the method of plowing under the trash, with the hope that the planter will benefit without going to much, if any, trouble or expense.

The writers supposed that the hibernation piles, as they are called, would do little good and no harm, but early in 1926 they made observations which show that such piles may be dangerous. The top layers of the piles were found to shed water like a thatched roof, perfectly protecting the trash underneath from the rain. Borers were found in the larger pieces of cane trash, and they were alive and healthy, ready to emerge as moths as soon as warm weather should come. On the other hand, borers in plowed-under trash were found to be dead. The larger pieces of cane were in a souring condition, and the borers had apparently been killed by the spoilage of their food, by the action of the acids on their bodies, or by both these causes combined.

A planter brought up the question why the borer but not the egg parasite would be killed in the decaying trash. The answer is that they are entirely different insects and have widely different habits. The parasite is undoubtedly in the adult stage and can move from one location to another. The borer is a larva dependent on the pieces of cane for food. It is unable to travel very far, and it is affected by the decay of its food, which surrounds it.

EXPERIMENT WITH THE HAWAIIAN BEETLE BORER PARASITE

The work of the entomologists of the Hawaiian Sugar Planters' Association Experiment Station is too well known to need any extended description. Suffice it to say that under the auspices of the very progressive sugar planters of Hawaii the world was searched for parasites of insects destructive to sugar cane, that they found many parasites, and that they succeeded in establishing many of them in the cane fields of Hawaii. The injury from insects has been greatly reduced, and millions of dollars' worth of sugar is being saved annually.

The parasite which contributed largely to the control of the weevil borer (*Rhabdocnemis* [*Sphenophorus*] *obscurus* Boisduval) was a tachinid fly (*Ceromasia sphenophori* Villeneuve) which was brought from New Guinea. As the habits of this beetle borer in boring through the cane stalks are much the same as those of the moth borer in Louisiana, Loftin suggested that Ceromasia be tried against the moth borer. The same suggestion was made later by L. O. Howard and the late W. D. Hunter, of the Bureau of Entomology. Frederick Muir, of the Hawaiian Sugar Planters' Association Experiment Station, who had discovered the parasite and introduced it into Hawaii, was consulted, and gave his opinion that it would not attack the moth borer. He stated that he had seen the moth borer (Diatraea sp.) and the beetle borer working together, and that Ceromasia confined itself to its beetle host.

The writers were prevented from introducing parasites known to attack the moth borer in Cuba, however, and it seemed worth while to give Ceromasia a trial. A cage isolated from ants was arranged, and in 2 feet of soil at the bottom of this cage a number of cane plants were set. Later nearly 200 stalks of cane containing tunnels

of the moth borer and probably many borers were secured and put into the cage, one end of each stalk being pushed into the ground. Otto H. Swezey, entomologist of the Hawaiian Sugar Planters' Association Experiment Station, in September, 1917, kindly gave directions for the preparation of this cage and caused puparia of Ceromasia collected in Hawaii to be sent to the writers, who placed the adults in the cage as soon as they emerged. Eighty-seven puparia were received, from which 23 flies emerged. About half of the adults were small, but many were of normal size. Swezey's instructions were followed closely, ants were kept out of the cage, the plants were sprinkled daily, and honey and overripe fruit were provided as food for the flies.

It was found that the infestation by the moth borer in the cage was far higher than that usually found in the field. The growing plants were so heavily infested that they did not make any appreciable growth throughout the remainder of the season. Though provided with possible hosts in such numbers, the parasites did not attack the borer. Some of the cane stalks were cut open at the end of six weeks, the length of a generation of the parasite in Hawaii, but no evidence was found that they had parasitized any borers, although many live borers were found. More cane was examined later with the same negative result.

EXPERIMENT WITH A PARASITE FROM CUBA

In 1915 Loftin went to Cuba to obtain, if possible, a tachinid parasite of the moth borer which had been reported by George N. Wolcott. It was found that while the moth borer was present, it was by no means as injurious as in Louisiana, and that the tachinid parasite *Lixophaga* (*Euzenilliopsis*) *diatraeae* Townsend (fig. 24) evidently had much to do with its comparative control.

Living puparia of the tachinid parasite were obtained and forwarded to the senior author in New Orleans from time to time during the summer of 1915. Cages of many kinds were utilized, although none of the type which had been found satisfactory in Hawaii with tachinids was used. In every experiment the parasites died without attacking the host larvae provided for them. Finally it was decided to release the adults in the fields at Audubon Park as soon as they emerged from the puparia. Following this action, during the next grinding season one puparium was recovered in a stalk of cane, and an adult of the species introduced from Cuba emerged from it.

No other parasites were found in 1916 and 1917, and further work in Cuba was prevented during those years. In 1918 a number of Louisiana sugar planters, headed by the late Clark D. Lebermuth and cooperating with the Bureau of Entomology, sent the senior writer to Cuba. Locating at Mercedes, Matanzas Province, he sent in over 600 parasites, but as efforts were still made to breed them in Louisiana many were wasted and probably none became established from this season's work. In 1919 and 1920 E. R. Barber, then of the Bureau of Entomology, collected parasites in Cuba—in 1920 with the aid of four student assistants provided by the sugar planters. The senior writer and W. E. Haley received the parasites in Louisi-

ana, and, profiting by experience, they attempted no breeding work but released the adult flies directly on the plantations of interested sugar planters. Colonies of from 10 to about 50 were released at a time. (Fig. 25.) Adults were released to avoid the introduction of secondary parasites which often emerge from the puparia of the tachinid.

In the falls of 1919 and 1920 a very few parasites in the pupal stage, and occasionally an adult fly, were found at some of the places of release, and since then a few parasites have annually been found at some of the places. Some have been found 2 or 3 miles from the nearest point of release, and one was taken at Pass Christian, Miss., about 60 miles from the nearest place of release. It seems probable, however, that the species was introduced accidently at Pass Christian in shipments of sugar cane from the Tropics.

The parasites have never been found except during grinding time, though many borers are handled earlier in the season. The parasites were released at 41 places in southeastern Louisiana, and they have been recovered at nearly 90 per cent of these places.

That the parasites are found at all indicates that they must be making a continued attack on the borer and therefore doing some good, but it would seem that they are no nearer controlling it now than when they were first introduced.

FIG. 24.—*Lixophaga* (*Euzenilliopsis*) *diatraeae*, Cuban parasite of the sugar-cane moth borer, greatly enlarged

In Louisiana the parasites have a difficult climatic condition to contend with. In the Tropics there is an abundance of sugar cane and borers at all times, but in Louisiana cold weather prevails most of the winter, for about three months no cane is growing, and there is a scarcity of borers until well into the summer. The parasite, after having reached some numbers in the fall therefore loses most of what it has gained, and the few parasites left have to make a fresh start in the spring.

It is possible that in the course of time the parasite will become acclimatized and may do much good in the control of the borer.

A PARASITE OF THE EUROPEAN CORN BORER

A braconid parasite, *Habrobracon brevicornis* Wesm., has been introduced from France to control the European corn borer in the

United States. At the suggestion of L. O. Howard a shipment of this species was sent to Louisiana from the European corn borer laboratory, Arlington, Mass. It was believed that this parasite would attack the sugar-cane moth borer as well as the European corn borer, and this surmise was correct.

When borers were supplied in cages in the laboratory they were stung readily, and the parasites depositing eggs on them came to maturity in a normal way. Under natural conditions, however, it was found that the parasite could not reach the borer in the stalks of sugar cane and corn. This fact undoubtedly accounted for its

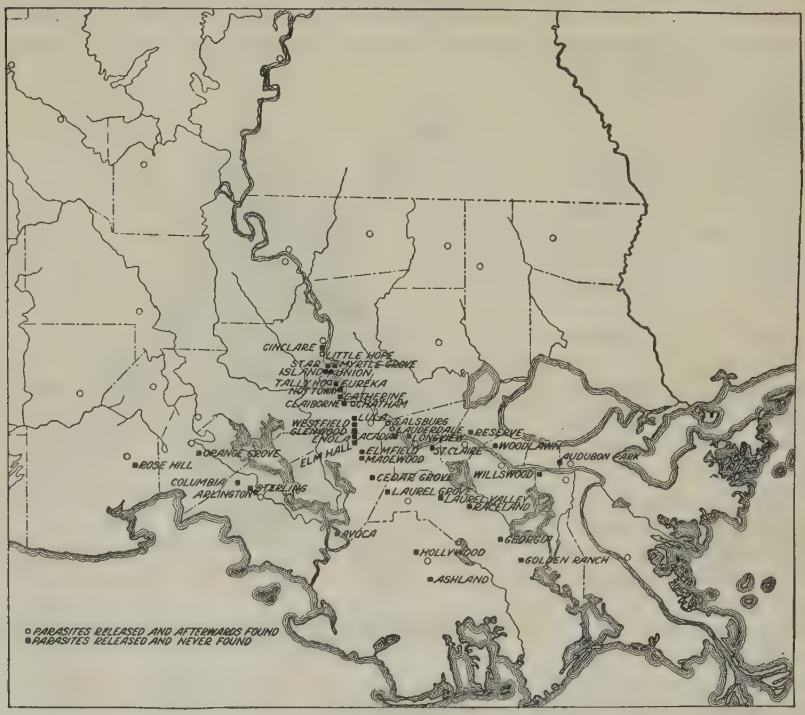

FIG. 25.—Points of release of Cuban parasite in Louisiana

failure when released in the fields. In 1922 about 200 of the parasites were released at Myrtle Grove plantation, Plaquemines Parish, La., and over 2,200 at Willswood plantation, Jefferson Parish. In 1923 over 2,000 were released at the sugar experiment station, Audubon Park, New Orleans, La. Even with so many parasites released, none was ever found in the fields afterwards. The Cuban tachinid established itself in several cases after the release of only 10 or 12 individuals, but it is apparent that the European braconid was altogether unable to reach the borers.

PLANTING BORER-FREE SEED CANE

The old recommendation to plant borer-free seed cane is a very good one, providing borer-free seed cane can be obtained. Ordinarily, however, it is not possible or practicable to obtain uninfested seed

cane. The tendency among planters, too, is to grind the best cane and to plant the cane that is not too greatly injured, more cane being planted to a given area if it is somewhat inferior.

Planting borer-free cane has been found to give a better stand as compared to planting infested cane, but at least on a small area the subsequent infestation can not be expected to be reduced.

To determine the effect of planting selected cane, four rows were planted with borer-free cane, and the adjoining four rows were planted with infested cane. The details of the experiment are shown in Table 10.

TABLE 10.—*Results from planting borer-free seed cane*

Kind of seed cane	Number of eyes at planting	Plants on June 19	"Dead hearts" on Sept. 1
Borer-free	2,125	1,720	8
About 38.5 per cent infested	2,004	1,343	6

The senior writer was told by a reliable plantation manager of the planting of borer-free cane at Pharr, Tex., in 1916. Although there were no borers in the seed cane, which had been procured from a section known to have none, the cane was badly infested at the grinding season.

A field of cane planted with borer-free seed somewhat resembles a field of corn in its relation to borers. Undoubtedly there are often no borers in the cornfield when the seed is planted, yet there may be a heavy infestation later. The borer moths evidently fly into the cornfield during the early spring, and they can as easily fly into a field planted with borer-free seed cane.

CHEMICAL TREATMENT OF INFESTED SEED CANE

Experiments have been conducted to discover the effect of fumigation and immersion on both the insects and the sugar-cane cuttings. Table 11 gives the results of dipping cuttings in various insecticides and fungicides and also of soaking the cuttings in the solutions for one hour, the borers afterwards being cut out to ascertain whether they were yet alive. The borers were kept and fed for about two weeks after the treatments.

TABLE 11.—*Effect on moth-borer larvae of immersion of infested cane cuttings*

Solution	Exposure	Number of larvae	Condition of larvae immediately after treatment	Penetration of solution in cane cutting	Condition of larvae 2 weeks after treatment
Bordeaux mixture 6-4-50	Dip	9	All alive	Penetrated, and was deposited on sides of holes.	7 alive.
	1 hour	6	do	Some of the stalks were evidently full of the solution.	All dead.
Fish-oil soap, ½ pound per gallon water.	Dip	9	do	Evidently penetrated the stalks.	8 alive.
	1 hour	11	All alive, 4 had emerged from cane and were in the solution.	do	9 alive.

TABLE 11.—*Effect on moth-borer larvae of immersion of infested cane cuttings*—Continued

Solution	Exposure	Number of larvae	Condition of larvae immediately after treatment	Penetration of solution in cane cutting	Condition of larvae 2 weeks after treatment
Nicotine sulphate (40 per cent nicotine), 1 part to 500 parts water.	Dip	10	9 alive, 1 small one dead between stalk and leaf sheath.	Probably penetrated the stalks.	4 alive.
	1 hour	7	6 alive, 1 dead	do	All dead.
Potassium sulphide, 3 pounds per gallon water.	Dip	7	All alive	do	4 alive.
	1 hour	10	do	do	1 alive.
Potassium sulphide, 1½ pounds per 10 gallons water.	do	10	All alive, 1 emerged from cane and in the solution.	do	4 alive.

Soaking the cuttings for one hour in either Bordeaux mixture or nicotine sulphate solution was found to kill all the larvae within two weeks. Only one larva was killed immediately, however, even after an immersion of one hour.

Eggs, larvae, and pupae were next subjected to immersions of one minute and one hour in the various solutions, with results as shown in Table 12. The larvae and pupae had previously been removed from the stalks of cane. A cluster of eggs, five larvae, or five pupae were used in each exposure.

TABLE 12.—*Immersion of eggs, larvae, and pupae of the moth borer in various solutions*

Solution used and stage of insect	Exposure	Effect within 2 days	Effect within 10 days
Bordeaux mixture:			
Eggs	1 hour	Did not kill	All hatched.
Larvæ	1 minute	do	2 dead out of 5.
Do	1 hour	do	None dead.
Pupae	do	do	All emerged.
Fish-oil soap:			
Eggs	do	do	All hatched.
Larvae	1 minute	do	1 dead out of 5.
Do	1 hour	do	2 dead out of 5.
Pupae	do	All killed	
Nicotine sulphate (40 per cent nicotine):			
Eggs	do	None hatched	All dead.
Larvae	1 minute	Did not kill	1 dead out of 5.
Do	1 hour	do	Do.
Pupae	do	do	All emerged.
Potassium sulphide, 3–100:			
Eggs	do	do	All hatched.
Larvae	1 minute	do	None dead.
Do	1 hour	do	1 dead out of 5.
Pupae	do	do	All emerged.
Potassium sulphide, 1½–100:			
Eggs	do	do	All hatched.
Larvae	1 minute	do	1 dead out of 5.
Do	1 hour	do	All healthy.
Pupae	do	do	All emerged.

Untreated eggs used as a check hatched as usual. Of 5 untreated larvae, 1 died within 10 days. All of the 5 untreated pupae were alive at the end of 10 days.

It will be noted that pupae immersed for one hour in fish-oil soap solution were killed, while eggs immersed for one hour in nicotine-sulphate solution did not hatch. The other solutions were ineffec-

tive. It is evident that larvae and pupae are more seriously affected by these two dips when in the cane stalks than when they are first taken out and then immersed. The reason for this is that a certain amount of fluid remains in the tunnels after the stalks are removed from the solution, and continues to affect the insects.

To test the effect of immersion and fumigation on the germination of cane cuttings, a number of tops and bottoms of the varieties D74 and Louisiana purple were treated in the fall and planted in the experimental fields. Table 13 shows the number of healthy plants on May 13 and at the grinding season. The "dip" was a very thorough immersion of the cuttings. Fish-oil soap solution apparently increased the percentage of germination, while no treatment can be regarded as injurious. Table 14 shows the weight in pounds at grinding, of cane from the treated seed. The fish-oil soap solution appears to have increased the tonnage, though this result is doubtful.

TABLE 13.—*Germination of treated seed cane*

Treatment	D74		Louisiana purple	
	Tops	Bottoms	Tops	Bottoms
Check (not treated)	[1] 18–73	20–79	44–89	36–71
Bordeaux mixture, dip (6–4–50 formula)	21–81	22–82	45–88	42–87
Bordeaux mixture, 1 hour immersion (6–4–50 formula)	26–94	28–88	46–86	29–81
Fish-oil soap, dip (one-half pound per gallon of water)	34–94	26–91	37–95	39–72
Fish-oil soap, 1 hour immersion	44–119	31–89	49–94	38–91
Check (not treated)	14–85	21–90	45–93	51–79
Tobacco extract (40 per cent nicotine as sulphate), dip (1 part to 500)	26–73	21–74	36–95	53–86
Tobacco extract (40 per cent nicotine as sulphate), 1 hour immersion (1 part to 500)	39–100	31–86	55–88	48–85
Potassium sulphide, 3 pounds to 100 gallons of water, dip	42–100	29–91	46–123	51–90
Potassium sulphide, 3 pounds to 100 gallons of water, 1 hour immersion	43–108	34–87	53–108	37–70
Potassium sulphide, 1½ pounds to 100 gallons of water, 1 hour immersion	35–118	26–91	45–112	42–94
Hydrocyanic-acid gas, 1 hour fumigation (1 ounce, 20 cubic feet, 1–2–4 formula)	39–103	[2]	53–96	41–77

[1] Number of healthy plants on May 13 (first figure) and number of stalks at the grinding season (second figure), the seed cane having been subjected to various treatments before planting.
[2] Seed cane taken by unknown person.

TABLE 14.—*Weight of cane grown from treated seed cane*

Treatment	D74		Louisiana purple	
	Tops	Bottoms	Tops	Bottoms
	Pounds	*Pounds*	*Pounds*	*Pounds*
Check (not treated)	160	192	230	160
Bordeaux mixture, dip	154	208	208	194
Bordeaux mixture, 1 hour immersion	188	164	214	184
Fish-oil soap, dip	224	204	226	176
Fish-oil soap, 1 hour immersion	238	220	212	214
Check (not treated)	158	238	214	188
Tobacco extract (40 per cent nicotine as sulphate), dip	142	138	168	158
Tobacco extract (40 per cent nicotine as sulphate), 1 hour immersion	168	158	178	138
Potassium sulphide, 3 pounds to 100 gallons of water, dip	158	158	228	148
Potassium sulphide, 3 pounds to 100 gallons of water, 1 hour immersion	178	164	188	134
Potassium sulphide, 1½ pounds to 100 gallons of water, 1 hour immersion	166	164	154	184
Hydrocyanic-acid gas, 1 hour fumigation	204	[1]	212	156

[1] Seed cane taken by unknown person.

After the development of vacuum fumigation by E. R. Sasscer, of the Bureau of Entomology, a method which has proved highly efficient in the destruction of insects in seed and cotton bales, it was planned to fumigate cane by this system. It was a matter of general surprise that larvae of the moth borer came out uninjured, even when subjected to a strong fumigation (6 ounces sodium cyanide, 9 ounces sulphuric acid, and 18 ounces of water to 100 cubic feet) for 1 hour, a vacuum of 25 inches being applied for 15 minutes and a pressure equivalent to normal air pressure for the succeeding 45 minutes, the combination of reduced pressure followed by normal pressure having been found very satisfactory for most species.

More recently a fumigation with calcium cyanide was tried in tight boxes. All the larvae were not killed except by a long fumigation with an excessive amount of the chemical. These were hibernating larvae in cane taken from the windrow, but it is possible that the larvae would not be so resistant to a fumigation of cane before planting in September. Such a test has not yet been made.

CHEMICALS ON PLANTED SEED CANE

The writers early realized the importance of destroying borers in seed cane, and to this end they conducted a number of experiments in applying chemicals to the soil close to the planted cane.

At first chemicals in the form of common fertilizers and insecticide dusts were tried, such as the following: Slaked lime, cyanamid, acid phosphate, dry Bordeaux mixture, dry lime-sulphur, ammonium nitrate, ammonium sulphate, kainit, nicotine-sulphur dust. No satisfactory results were obtained, and then a series of more or less odorous chemicals were tested, paraformaldehyde, paradichlorobenzene, a commercial grade of chloronaphthalene, p-dibromobenzene, naphthalene, oil of cloves, oil of sassafras, oil of cedarwood, aniline, chlorobenzene, nitrobenzene, dichlorobenzene, bromobenzene, alpha-chloronaphthalene. Paradichlorobenzene was the only chemical which killed borers in the seed cane.

A considerable number of experiments were run with this chemical. It was found that by applying it by hand in a laboratory test the borers in the stalks could be killed without affecting the germination of the cane, but on a field scale it was impossible to follow this method. The laboratory method required that the cane be perfectly straight, that the soil be pulverized, and that the chemical be placed not on the cane but at a given distance from it.

A test was made in the field, scattering the paradichlorobenzene on each side of an open furrow with seed cane at the bottom, the cane then being covered with the treated earth. On using 14 and 16 pounds per acre, the successful dosages in the laboratory tests, the germination of the cane was decreased, and few if any borers were destroyed. A method was then devised of mixing the chemical with sand and sprinkling it at the bottom of a furrow ready to receive the cane. About 1,000 pounds of sand were used per acre, with the same quantities of paradichlorobenzene as in the previous experiment. The germination of the cane was lowered, but no borers were killed.

Calcium cyanide was tried, and an excessive amount (three-fourths pound to 6 feet of row) killed borers gradually but also killed all eyes of the cane. A field experiment in which from 16 to nearly 900

pounds per acre was used was then started. The chemical was placed in the open furrow, and the cane was laid in and covered with earth. As the soil had not been properly prepared (the experiment was a co-operative one), a perfectly fair test was not obtained. After 10 days a live and healthy borer and no dead borers were found in the planted stalks treated with the maximum application. A strong odor of cyanide was still in the soil, but the eyes of the cane were apparently healthy.

The prospect of successfully treating planted seed cane with dry chemicals is not favorable.

FLOODING AS A CONTROL MEASURE

In an attempt to drown the borers in the cane after planting, part of a field at John M. Caffrey's Columbia plantation, near Franklin, La., was flooded. It was found very difficult to get and hold the water on the field in sufficient quantity, and only the lowest part of the field was successfully covered. It appears that flooding injures the cane stubble and the soil, and it is not the kind of irrigation which is recommended by engineers.

THE HOT-WATER TREATMENT

In 1922 E. W. Brandes, of the Bureau of Plant Industry, told the senior writer of a treatment of seed cane which he had used against the sugar-cane mosaic disease. This consisted of soaking the cane in heated water. Although the treatment was not effective against the mosaic disease, it had been found that the insects on and in the stalks of cane were killed and that the germination of the cane was stimulated. Acting on Brandes's suggestion, the writers carried on a number of experiments and finally decided that the best treatment was to soak the cane for 20 minutes in water heated to 122° F. (50° C.). Later in the year W. G. Taggart, assistant director of the sugar experiment station, treated enough seed cane to plant several rows. Under field conditions it was found that while the growth of the cane was greatly stimulated in the fall, the winter retarded the growth to such an extent that plants from untreated "seed" overtook those of the treated "seed," and that the stimulation was not of any practical importance, at least in Louisiana. On the other hand, it is realized that if a cold winter should follow excessive stimulation of fall-planted cane some injury might result.

Sprouted eyes were found to be killed by the hot-water immersion, both by the writers in Louisiana and by Yoder and Ingram (*35*) in Georgia. The writers also found that cane taken from the windrow and treated in the spring was severely damaged. In March, 1923, such cane was treated at Chatsworth plantation, near Baton Rouge. About 10 per cent of it sprouted, but many more than 10 per cent of the eyes were killed. On May 14 the germination of treated and untreated cane was compared. In the rows of treated "seed" there were 246 plants, while the same amount of untreated "seed" had produced 1,519 plants. Eyes on the treated stalks had died without sprouting. No stimulation of growth was observed.

It is the opinion of the writers that in Louisiana, at least, the hot-water treatment should be limited to cane planted in the fall.

It still remains to give the treatment an adequate test under plantation conditions, but on account of the flight of the moths and the danger of their reinfesting a borer-free area, the experiments should be carried on over an entire plantation at least, a scale of work not within the reach of the writers.

THE COLD-WATER TREATMENT

After experimenting with hot water as a borer control, the writers immersed bored stalks in cold water to determine for their own satisfaction the length of immersion necessary to destroy the borers. It was found that all borers were dead after an immersion of 72 hours, though most of them were dead after an immersion of 24 hours.

In the fall of 1924 this treatment was given a practical test by E. A. Pharr, on Avoca plantation, near Morgan City, La. It happens that this plantation borders on wide watercourses, and at two or three convenient points large water-tight barges were moored and filled with seed cane done up in wagon-load bundles and tied with chains. Water was then pumped into the barges. Many dead borers of various stages were observed on the surface of the water. After 72 hours the water was pumped out, and the cane was removed. The bottoms of the barges were found to be white with dead borers. One barge load was given a treatment for only 65 hours, and although many borers were killed some remained alive and reentered the stalks of cane.

Only one running stalk of this treated cane was planted in the rows instead of two, and with half as much cane planted a better stand was secured. The germination of the cane was somewhat stimulated, so that early in the year there was a stand of rather tall plants, but later the untreated cane equaled the treated cane in height. On account of the smaller amount of seed cane required, because it was unnecessary to make the usual allowance for damage to the planted seed cane by the borer, Mr. Pharr estimated that the treatment really cost nothing.

The plants growing from the treated cane were, of course, not found to be immune to the borer, as some persons seemed to expect, and on account of having a fairly heavy growth early in the season they probably attracted borer moths from untreated fields. At any rate, the fields of treated cane were rather heavily infested during the following fall—more badly bored, indeed, than those of a neighboring plantation which had been taken as a check. Unfortunately the bad results of this one season's work has prevented the planters from giving the cold-water treatment any further test.

It should be pointed out, however, that the treated fields were in the midst of untreated-plant and stubble fields. The cold-water treatment is worthy of a large-scale test under more isolated conditions.

Some sugar planters seem to think that barges in a stream are absolutely necessary for the cold-water treatment, whereas tanks or ponds on dry land would do as well. One plantation manager has proposed a pond into which narrow-gauge cars loaded with cane could be run on tracks.

RECOMMENDATIONS

The writers believe that much could be accomplished by the observance of the following recommendations:

Pieces of cane left about the fields, derricks, and factories after the grinding season should be destroyed during the winter. Cars in which sugar cane is shipped, especially if they go into noninfested territory, should be kept free of such scraps.

The "trash," "leaves," or "shucks" left on the fields after cutting should not be burned, but should be lightly covered with earth in the fall and plowed out in the spring. This practice has been found to decrease the borer infestation, especially where adopted over large or isolated areas. In addition, the soil is fertilized by the buried trash and its mechanical condition is greatly improved.

Cane should be cut low, preferably by machine, so as not to leave tall stubble, which harbors the borer.

An effort should be made to prevent large grasses from growing on the plantation headlands and ditch banks.

Experiments on a plantation scale should be conducted to determine whether corn can be replaced on sugar plantations by some other crop such as soy beans.

Experiments on a plantation scale should be made with the hot-water and the cold-water treatments of seed cane.

The writers suggest that the Louisiana sugar planters arrange several experiments, as mentioned above, on entire plantations, guaranteeing the owner of a plantation against any loss that he might suffer as a result of an experiment. All the sugar planters would benefit, and none would suffer an overwhelming loss. This seems to be the only way that large-scale experiments can be conducted. Owing to the flight of the moths of the borer, experiments on less than an entire plantation are not satisfactory.

In addition to the foregoing, further effort should be made to introduce foreign parasites.

SUMMARY

The sugar-cane moth borer has been responsible for a loss in sugar production to Louisiana alone of 292,198 tons in the five years 1922 to 1926 inclusive, and no estimate is available as to loss to corn and other crops which are attacked.

The injury is caused by the tunneling of the borer into the interior of the stalk, which kills the cane, if it is young and tender, or leaves it weakened if more mature, and a ready victim of wind and fungus, and in any case lowers the quantity and quality of the juice produced.

The insect is a native of the West Indies or South America, but has probably been present in Louisiana since long before 1857, and is now found also in Florida, Mississippi, and Texas.

Three species of Diatraea are found in the United States, and two of them, *Diatraea saccharalis*, the sugar-cane moth borer, and *D. zeacolella*, a southern corn pest of similar habit, are often confused, as the sugar-cane moth borer also readily attacks corn.

The insect will breed in sorghum and in a number of other grasses as well.

Emerging in the spring, the adult female deposits her eggs on the young cane shoots; the resulting larvae soon bore into the stalk, develop, pupate, and emerge again as moths; the cycle being repeated in as many as four generations before the cold weather will hold the existing larvae over until spring.

The eggs are laid in clusters. The larvae, when full grown, are about an inch long and an eighth of an inch wide, and the adult, a straw-colored moth, measures about an inch across the wings.

The egg stage has been observed to range from 4 to 9 days, averaging, however, 5 days in Louisiana. The larval stage is begun on the leaves, but after the first molt the larvae enter the stalk to do their damage in secret, protected from enemies and sprays. Ordinarily there are 5 molts, but more are common, and up to 14 have been recorded for hibernating larvae. The larval period ranges from about 18 to 30 days in summer to 276 days for hibernating individuals. The pupal period also varies widely, but averages 8.5 days, and is passed in an enlargement of the tunnel made by the larvae in the stalk. The adult may live from 3 to 8 days, the entire life cycle generally requiring about 43 days.

The seasonal history may be assumed to begin in the latter part of April. The first brood is not numerous enough to do great damage, but assuming four generations, and 200 eggs for each female, it is easily seen that a single pair of adults emerging in the spring might have a total progeny of 202,020,200 in one year. Naturally, not all can survive, but the possibility of enough borers to provide 10,000 for every stalk of cane in an acre, coming from one pair of adults, accounts for the high infestation by fall.

Natural control is furnished to some extent by any period of excessive rainfall during the winter and spring, by freezing weather, and probably to the greatest degree by an egg parasite, *Trichogramma minutum*.

Artificial control methods include provision for the harboring of the above-mentioned parasite by leaving the trash in the fields (but not including pieces of cane); the collection and destruction of scraps of cane left about the plantation; the possible substitution of some other crop for corn, as the broods develop faster and in greater numbers on corn than on cane; low cutting of the cane; the destruction of large grasses; the introduction of foreign parasites; and the treatment of seed cane to kill any contained larvae.

The most promising method of treating seed cane is that of submerging it in water to kill the larvae, but this or any other control measure is ineffective unless applied over a large area, as in the summer the moths will fly to fields planted with treated seed and start a new infestation if they are allowed to breed in any near-by uncontrolled section.

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